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EFFECT OF FORAGE TYPE AND CORN SUPPLEMENTATION ON ANIMAL PERFORMANCE AND MEAT QUALITY

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ABSTRACT

Angus x Hereford steers (441 ± 24 kg; n = 32) were used in a 2-yr study (2011 and 2012) to examine forage type (legume species, alfalfa and soybeans LG vs. grass species, tall fescue and sudangrass, GR) and daily corn supplementation (0%, NS, vs. 0.75% BW, CS) on animal performance and carcass quality. Steers grazed (May-August) for a total of 98 d and 105 d in 2011 and 2012 respectively. Upon completion of the finishing period, steers were slaughtered and carcass data were collected. Steaks (2.5 cm thick) from the *longissimus dorsi* muscle (LM) were collected for measurement of proximate analysis and tenderness after different postmortem aging times (2, 4, 7, 14, 28 d). Data were analyzed in a mixed model using a 2x2 factorial arrangement of treatments. Steer was the experimental unit and year included as a random effect. Corn supplementation (CS) increased ($P < 0.05$) average daily gain (ADG), hot carcass weight (HCW), dressing percentage (DP) and tended ($P < 0.06$) to increase fat thickness at the 12th rib (FT). CS also increased ($P < 0.05$) yield grade (YG) and tended to increase ($P <$ 0.07) quality grade (QG). In terms of forage, LG increased ($P < 0.05$) DP and HCW, with a tendency to increase ADG ($P < 0.06$). CS resulted in lower ($P < 0.05$) concentrations of CLA c9t11 and n-3 FA. Steers receiving CS had a higher ($P < 0.05$) n-6:n-3 ratio (3.1 vs. 2.4), but both are lower than the 4:1 ratio recommended by health officials. Grazing GR increased ($P < 0.05$) saturated FA due to greater ($P < 0.05$) concentrations of stearic (C18:0) acid. LG forage increased calcium content of the LM. Tenderness was only affected ($P < 0.05$) by postmortem aging. Grazing legumes during finishing improves HCW and DP, and tends to improve ADG. Corn grain supplementation to grazing steers

improved animal performance while not negatively impacting the nutritional qualities of the meat.

DEDICATION

This thesis is dedicated to my parents, Daniel and Stephanie, for their constant support and motivation through this process; to my fiancé, Julia, for her unconditional love and positive attitude; and finally to Chase and John, of the Warren-Wilson College Farm Crew, for instilling in me a love for the land and a drive to work hard and learn more about sustainable agriculture.

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Introduction

Forage-finished beef remains a niche market in the U.S., but it continues to grow each year in terms of consumer demand and producer interest. The U.S. forage-finished beef industry, according to a recent study by Winrock International (Fisk et al., 2012), is estimated to account for 3% of total beef sales with a 20% increase annually compared to only 3% annual growth for the commodity beef market. This is in part due to perceived environmental benefits and human health benefits associated with eating forage-finished beef compared to concentrate-finished (feedlot) beef.

According to Boody et al. (2005), well-managed forage-based beef systems would greatly reduce emission of heat-trapping greenhouse gases (40 percent), decrease fuel use, decrease soil erosion (50 to 80 percent), and improve water quality. Pelletier et al. (2010) also found reduced greenhouse gas emissions in pasture-based systems and in addition to the work of Boody, decreased levels of eutrophying emissions. Sithyphone et al. (2011) compared feed cost and environmental impact between hay and concentrate fattened Wagyu cattle in Japan and reported a 78% reduction in feed cost and a 79% reduction in CO_2 equivalents for the hay-fattened cattle. A 2006 review of pasture-based beef production (Clancy et al., 2006) reported general consensus amongst scientists that raising cattle on well-managed pastures will decrease soil erosion and increase soil fertility, improve water quality due to decreased pollution, improve animal health and welfare as well as provide the producer with more profit per animal.

In addition to environmental benefits, a number of human-health benefits have been identified with the consumption of forage-finished beef. In general forage-finished beef products have lower total fat and higher proportions of health promoting fatty acids (Duckett et al. 2009), antioxidants (Yang et al. 2002; Duckett et al. 2009) and B-vitamins (Duckett et al. 2009). For these reasons, forage finished beef has the potential to command a higher price through niche markets and direct marketing.

Some forage-finished producers direct marketing choose to label their product as "Grass-Fed". According to the USDA Agriculture Marketing Service (2007), to market an animal as grass-fed (forage-finished) the producer must adhere to the following guidelines during the animal's life:

> "Grass and forage shall be the feed source consumed for the lifetime of the ruminant animal, with the exception of milk consumed prior to weaning. The diet shall be derived solely from forage consisting of grass (annual and perennial), forbs (e.g., legumes, *Brassica*), browse, or cereal grain crops in the vegetative (pre-grain) state. Animals cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season. Hay, haylage, baleage, silage, crop residue without grain, and other roughage sources may also be included as acceptable feed sources…"

With increased consumer interest in forage-finished beef and consumption on the rise, there is a positive outlook for producers.

According to a CME group daily livestock report from December 20, 2011, Americans are consuming less animal products, 12.2% less than 2007 and 25% less than

1980 on a boneless equivalent basis, per capita. Though this includes pork and poultry, the same is true for beef and veal alone and much of this consumption decline is related to beef consumption. According to the (October 2012) USDA report on Livestock and Poultry: World Markets and Trade, by October of 2013 Beef consumption is down 8% since 2008. The CME group report attributes the decline in consumption to increased U.S. exports, higher feed costs associated with expensive oil and increasing ethanol production, as well as forty years of federal agencies "waging war" on animal protein consumption in the U.S. Though export market demand and government policy are generally out of the producer's control, feed costs associated with production systems are not.

With increased costs of feed and transportation, producers that choose to forage-finish and direct market may have an economic advantage relative to more traditional beef production systems (Lozier et al., 2003). Finishing cattle in this manner requires high quality forages to match animal nutrient needs for adequate gains. Research by Dierking et al. (2010) demonstrated better animal performance when steers where finished on legumes and grass compared to grass alone. However, even high quality forages cannot always meet animal demands and a producer finishing steers on pasture may benefit from high-energy supplementation. Finishing animals on pasture with an energy supplement provides the opportunity to not only improve animal performance (Elizalde et al., 1998; Roberts et al., 2009) but also increase stocking rate (Horn et al., 2005; Pavan et al. 2007; and Rouquette et al. 2007).

Forage Finishing and Grain Finishing

Forage-finished beef is not a new concept in the U.S. and studies first appear in the literature during the 1930s (Brown, 1954). With the emergence of federal grain subsidies during the 20th century, grain finishing beef cattle became more affordable and feedlots quickly became the norm (Runge, 2004). Bowling et al., (1977) reported that interest in forage-finished beef cattle in the U.S. tends to coincide with periods of food grain shortages and high grain prices. With rising input costs and thus grain prices, early research on forage-finished beef (Oltjen et al., 1971; Bowling et al., 1977; Cross & Dinius, 1978; Bidner et al., 1981; Smith et al., 1977) was conducted to explore animal performance, meat composition, and consumer acceptability of forage-finished beef compared to feedlot beef.

A renewed interest in forage-finishing came in the 1980s when consumers became increasingly concerned about the fat content in red meats (Crouse et al., 1984). This emerging interest spawned research to investigate forage-finishing and decreased grain feeding in beef production as a means to produce a leaner product (Crouse et al., 1984; McMillin et al., 1990; Duckett et al., 1993). This is in part due to high grain prices ($6.97 per bushel of corn as of Feb 13, 2013) but also research that indicates including forages in a beef animal's diet provides a number of health benefits to the consumer when compared to a grain diet (Yang et al., 2002; Duckett et al., 2009). Forages and grains not only lead to differences in meat quality; but also prior to human consumption, the different types of feeds give rise to differences in animal performance.

Animal Performance: Considering animal performance is important for two reasons. Cattle that are more feed efficient and gain weight faster, finish earlier and are more profitable. Alternatively cattle with rapid gains prior to slaughter produce more tender meat compared to slower finishing cattle (Aberle et al., 1981). This is due to higher levels of proteolytic enzymes in the meat tissue at the time of harvest; which results from higher levels of protein turnover in the rapidly growing cattle (Shackelford et al., 1994). The work of Perry et al. (2002) demonstrated a positive curvilinear relationship between palatability and animal growth rate. Palatability increased as growth rate increased and plateaued around 1.2 kg/d. This is in agreement with more recent work by Perry et al. (2005) that concluded an increased growth rate resulted in more palatable or tender meat. Though somewhat consistent with the previous research of Perry et al. (2002), these results, surrounding growth rate and palatability (Perry et al., 2005), were concluded to be confounded by breed types, production locations, and the two cuts of meat chosen for the experiment. The most consistent relationship found in this study was an increase in palatability of the striploin with increased growth rate. The primary problem with forage finishing, is that most forage systems do not provide the proper combinations of protein and energy for cattle to grow at a rate fast enough to deposit adequate fat.

Beyond palatability, it is well documented that cattle finished solely on forages alone have lower rates of gain compared to those finished on concentrate diets. Bowling et al. (1978) reported that steers finished in a feedlot reached final weight (518 kg) and grade approximately 6-months prior to their counterparts on forage alone. Bidner et al.

(1981) reported steers finished on forage took an additional 160 days to reach final body weight (476 kg) compared to those consuming grain. This can be attributed to the fact that, with exception to very high quality forages, diets high in forages tend to have a decreased net energy and thus result in slower animal gains (Bidner, 1981). Berthiaume et al. (2006) reported a 21% increase in ADG for cattle finished on soybean meal and barley compared to those on forage alone. More recent research from Duckett et al. (2013), using 128 Angus-Crossbred steers, reported a higher ADG (1.61 vs 0.91 kg/d) for the concentrate diet compared to the forage diet.

The research above indicates poorer animal performance on forages compared to concentrate, but it has long been known that high quality forages along with good genetic selection can diminish the differences seen in animal performance between grain and forage finished cattle (Brown, 1954). Not only do cattle finished on forage exhibit differences in performance but also in carcass quality.

Carcass Quality: In general, carcass quality is viewed as being less desirable in forage-finished beef compared to those finished on concentrate. Kerth et al. (2007) reported steers finished on forage to have less fat and muscle. Earlier work by Schaake et al. (1993) also found less fat in the LM of forage-finished steers. There are a number of studies that report lower USDA Yield Grade values (Schaake et al., 1993; Kerth et al., 2007, Duckett et al., 2007) for forage-finished steers. Lower Yield Grade values mean a higher red meat yielding carcass, which can be attributed to less fat deposition. Duckett et al., (2007) reported a yield grade of 1.6 vs 2.4 for pasture compared to feedlot. Kerth et al. (2007) found grain finished steers had a yield grade of 2.96 vs 2.25 for steers finished on ryegrass pastures. Though forage-finished steers tend to have a higher yielding carcass, they do not have as high of a Dressing Percentage (DP), another important indicator of profitability. Duckett et al. (2007) reported a DP of 61.8 percent for feedlot steers and only 54.0 percent for pasture. These values for pasture are substantially lower than the work of Bowling et al. (1978) whose steers on pasture dressed out at 60.7 percent with feedlot being similar to Duckett et al. (2007) at 63.0 percent.

Values for USDA Quality Grade (expected eating characteristics) show more variation amongst studies. Some studies (Bidner et al., 1981; Cox et al., 2006, Kerth et al., 2007) indicate no difference in Quality Grade between forage-finished and concentrate-finished cattle; whereas others (Craig et al., 1959; Bowling et al., 1978; Duckett et al., 2007) found a lower Quality Grade for steers finished on forage compared to those on concentrate. Both Bowling et al. (1978) and Duckett et al. (2007) reported a USDA Quality grade of choice for grain-finished steers and select for forage-finished steers. This makes sense, as marbling along with maturity, are the two factors that comprise quality grades. The differences reported for quality grade between forage-finished and concentrate-finished steers are most likely attributed to differences in diet and finish time (equal carcass endpoint or equal time endpoint). Forage-finished beef is typically leaner with less marbling (Schaake et al., 1993; Duckett et al., 2007) and less subcutaneous and KPH (Craig et al; 1959; Bowling et al., 1977; Schaake et al., 1993).

In contrast, Roberts et al. (2009) reported that high quality ryegrass produced forage-finished beef with no differences ($P > 0.05$) in marbling or KPH compared to grain finished beef. In this study there was a positive linear relationship between supplementation level and HCW, DP, and ADG; however, the steers on winter annual ryegrass alone only had 6% reduction in HCW compared to feedlot finished, with similar reductions for DP and ADG compared to grain finished steers. This is in agreement with the work of Steen et al. (2003) who found similar results when cattle finished on high quality ryegrass (higher in energy compared to other forages). They concluded that forage-finishing on annual ryegrass increases lean production efficiency, with less fat and higher concentrations of health promoting fatty acids (Steen et al., 2003). The differences in animal performance and carcass quality observed between diets were also reported in meat composition.

Meat Quality: As the CME Daily Livestock Report from December 11, 2011 stated, current decline in meat consumption could be related to clever marketing from anti-meat groups. This has resulted in a current historic low for beef consumption (54 lbs per person in 2012), however it still remains a large part of the U.S. diet. According to a USDA long-term projections report from 2012, meat consumption is expected to increase to 60 lb per person by 2020. Regardless of production system, beef is a nutritious product low in sodium, high in vitamins A, D, E, B_6, and B_{12}, and minerals, iron, selenium, and zinc (Williamson et al., 2003 and Biesalski et al, 2005).

Beef is relatively high in intramuscular fat (IMF) compared to pork and chicken (Hocquette et al., 2009). Enser et al. (1998) found beef sirloin to have 3.8% IMF compared to 2.8% for pork. Based on the review by Hocquette et al. (2009), chicken breast normally contains 1% or less of IMF, with dark meat having 4%-5% IMF. Other than fat, the chemical composition of muscle is generally the same amongst species (about 75% water, 19%-25% protein, and 1%-2% minerals and glycogen) and much of the health related concerns regarding meat consumption are related to fat. Intramuscular fat plays an important role in the quality of meat, including sensory properties and health qualities.

Human health experts recommend reducing saturated fatty acid (SFA) intake in the diet. This is because SFA are linked to increased blood serum levels of low-density lipids (LDL), which increase the risk of coronary heart disease (Keys, 1970). SFA also raise total blood cholesterol levels with exception of stearic acid (C18:0), which is considered neutral (Williamson et al., 2003 and Yu et al., 1995) because it has no net impact on serum cholesterol. Forage finished beef typically has higher concentrations of stearic acid (Duckett et al., 2009; Aldai et al., 2011). In contrast, research by Nassu et al. (2011) found no difference in stearic acid concentration between corn silage and forage-only diets. Overall there are many studies that indicate meat from forage-finished beef has higher levels of SFA (Dugan et al, 2007; Duckett et al., 2009; Aldai et al., 2011; Duckett et al., 2013). The increase in SFA seen in the meat from forage-finished steers may be attributed to the increased intake of forages, which are known to contain a waxy cuticle, rich in long-chain esters compared to concentrates (Post-Beittenmiller, 1996). Though the meat from forage-finished cattle tends to have higher proportions of SFA, it is lower in the cholesterol raising SFAs (C14:0 and C16:0) compared to concentrate finished. Duckett et al. (2009) reported significantly lower levels for pasture compared to concentrate for both C14:0 (2.46% vs 2.79%) and C16:0 (24.34% vs 26.68%).

Finishing cattle on forage generally reduces total fat content of the meat (Duckett et al. 2009). Duckett et al. (2009) found steers finished on concentrate had 4.1% lipid as compared to only 2.3% for pasture. These results are similar to the work of Realini et al. (2004) who reported concentrate finished beef had twice as much fat (3.18% vs 1.68%) as forage finished. According to multiple studies (Duckett et al., 2009; Nassu et al, 2011, Duckett et al. 2013), the only health promoting FA to be lower in forage-finished beef is oleic acid (C18:1), which generally comprises 30%-50% of total FA. In contrast, French et al. (2000) found no difference between concentrate and forage for oleic acid. Recent work (Duckett et al., 2013), found oleic acid to be 32.8% in forage-finished compared to 41.6% in concentrate finished. These higher values of oleic acid seen can be attributed to the endogenous desaturation of stearic acid (C18:0) by tissue enzyme stearoyl-coa desaturase (SCD). Duckett et al., (2009) found elevated SCD activity in adipose tissue of concentrate finished steers. In addition to oleic acid, Duckett et al. (2013) reported total MUFA to be lower in forage compared to concentrate finished, (35.9% vs 45.9%, respectively). Monounsaturated fatty acids, like oleic acid, are considered antithrombogenic, meaning they reduce serum LDL while raising serum high-density lipids (Ulbricht and Southgate, 1991; Kris-Etherton, 1999).

Two other important human health indicators are associated with polyunsaturated FA (PUFA). According to the World Health Organization and Food and Agriculture Organization's join expert consultation, (WHO/FAO, 2008) recommendation, in order to reduce cardiovascular disease (CVD), SFA should be replaced by PUFA in the diet. This is because, like MUFA, PUFA are also antithrombogenic (Ulbricht and Southgate, 1991).

The ideal amounts of these FA can be defined by the PUFA to SFA ratio (P:S) and the optimal P:S in the diet is 0.45 or higher (Department of Health, 1994). Ruminant meat is very low in P:S. Recent work by Nassu et al. (2011) reported forage-fed beef to have a ratio of 0.12 and silage-fed beef to have 0.09. These results are similar to the work of Duckett et al. (2009) who found P:S for concentrate to be 0.10 for feedlot and 0.14 for pasture. Though forage-finished cattle have a higher P:S ratio, both production systems are well below the recommended ratio. The low P:S values observed in these studies are a result of ruminal biohydrogenation (Enser et al., 1998), where following ruminal lypolisis, microbial enzymes act on unsaturated FA, removing double bonds to produce SFA (Hatfield et al. 2008). Even studies that include flaxseed, the richest plant source of the PUFA, α-linolenic acid, do not increase the ratio enough. Nassu et al. (2011) supplemented cows on pasture and on silage with flaxseed and the highest ratio found (pasture + flax) was only 0.13. Studies like this demonstrate the challenge of altering FA composition in beef due to the nature of the rumen.

The other important human health consideration surrounding PUFA is the ratio of omega-6 to omega-3 FA (n-6:n-3). Of the PUFA, omega-3 FA are considered to be more healthy than omega-6. Health officials (Department of Health, 1994) recommend lowering n-6:n-3 in the diet to 4:1 or less. The work of Okuyama (2001) found a high n-6:n-3 to be associated with a higher risk of CVD, and that the ideal ratio within the diet to be 1:1; however ≤4:1 is considered good. Cattle finished on forages have higher omega-3, particularly α-linolenic acid, (Enser et al., 1998; Mandell et al, 1998.; French et al, 2000; Duckett et al, 2009; Aldai et al., 2011) which is responsible for the lower n-6:n-3 ratio reported in forage-finished cattle. Interestingly, studies (Nassu et al., 2011) that incorporated flaxseed into a concentrate diet showed no difference in n-6:n-3 due to the high concentration of α-linolenic acid in the diet.

The final group of FA in beef to receive a lot of discussion are known as conjugated linoleic acids (CLA), which are geometrical isomers of linoleic acid (C18:2 *cis*-9, *cis*-12). These FA are important for their observed anti-carcinogenic and anti-atherogenic effects, especially the *cis*-9 *trans*-11 isomer of CLA. The famous discovery began in 1979 when Pariza et al. found that the lipid extract from fried ground beef contained anti-carcinogenic properties, and later Pariza et al. (1986) found similar effects from the raw extracts of ground beef. Ha et al. (1987) was able to demonstrate that these properties were associated with the CLA in the beef. Recent work by Tricon et al. (2005), and Bhattacharya et al. (2006) further demonstrated the anti-carcinogenic effects of these FA while others (Field and Shley, 2004; Bhattacharya et al. 2006) demonstrated anti-atherogenic properties. Overall these papers concluded that more work needed to be conducted to 'validate' the claims. *Trans*-11 vaccenic acid (TVA; C18:1 *trans*-11) is also discussed in conjuction with CLA because it can be converted to the *cis*-9 *trans*-11 isomer of CLA in humans. Duckett et al. (2009) demonstrated how forage finishing beef increases TVA (3.34% vs 0.32%) in beef. Other studies have demonstrated how the addition of flaxseed to the diet increases TVA concentration in meat. He et al. (2011) and Nassu et al. (2011) both found significantly higher levels of TVA in forage fed cattle supplemented with flaxseed (2.7%-5.9% vs. 0.7%-1.49%). Aldai et al. (2011) concluded that 2 months of concentrate feeding reduced levels of TVA from 2.41% to 1.84%. This can be attributed to the fact that TVA is a biohydrogenation intermediate of linoleic acid.

A final aspect to consider is the antioxidant content of the meat and the role that antioxidants play in protecting meat quality. Oxidation has been considered the greatest reason behind losses in flavor, color, texture, and nutritive value of meat (Gatellier et al., 2004). Forage-finished beef has a higher susceptibility to oxidation because of the high levels of PUFA (Yang et al., 2002, Luciano et al. 2011). In contrast, the leaf tissue of forages is naturally high in vitamin E, carotenoids, and flavonoids and studies have found higher concentrations of these antioxidants in forage finished beef (Daly et al., 1999; Gatellier et al., 2004). Vitamin E (α-tocopherol) is the primary antioxidant in animal tissue (Wood & Enser, 1997). Daly et al. (1999) reported a vitamin E concentration of 3.66 ppb for pasture-fed beef and 2.53 ppb for concentrate-fed beef, a 31% reduction. Luciano et al. (2011) reported a 54% reduction for concentrate from 2.59 μg/g to 1.15 μg/g. Duckett et al. (2009) found an even larger reduction (74%) between pasture and concentrate beef, 773.4 μg/100g vs 199.3 μg/100g. Duckett et al. (2009) also reported a decrease in β-carotene, an additional antioxidant, for the concentrate diet (43.88 μg/100g vs 28.53 μg/100g).

Wood & Enser (1997) and Mercier et al., (2004) suggest that even though forage-finished beef has higher levels of pro-oxident PUFA, the high concentration of vitamin E can protect against lipid-oxidation, the main contributor to off-flavor as well as the oxidative change of oxymyoglobin to the brown metmyoglobin. Results to validate this are mixed however and Realini et al., (2004) reported that cattle on concentrate supplemented with Vitamin E showed increased lipid stability, but no improvements in color stability. In contrast, Luciano et al. (2011) concluded that grass-based feeding systems give rise to higher levels of Vitamin E within the meat which lead to an increase in meat color stability. The increase in stability did not correspond to the differences in lipid-oxidation suggesting that Vitamin E in muscle alone does not explain the resistance of meat to oxidative deterioration.

Beef Cattle Production in Argentina

According to USDA Food Agriculture Service, Argentina is the 6th largest producer of beef worldwide. In recent years however, Argentina's beef industry has been scaled back. This is primarily due to land competition with other profitable agriculture commodities such as soybean (Arelovich et al., 2011). In order to maintain or increase beef production on less land, federally subsidized feedlot-finishing systems have recently been implemented to intensify production (Arelovich et al., 2011). Other producers have been developing different ways to intensify their production of beef cattle on forages with energy supplementation such as corn grain or corn silage (Arelovich et al., 2011).

Often considered a "grass-fed beef country", in Argentina, beef cattle are routinely finished on forage-based systems that typically include corn supplementation and in some cases an ionophore, such as monensin, which has been shown to improve live animal weight gain and final body weights (Packer et al., 2011) while reducing occurrence of frothy bloat (Branine and Galyean, 1990). With a desire to intensify production on forages and a recent consumer interest in the nutritional eating qualities of beef around the world, studies in Argentina have sought to explore how different diets impact animal performance as well as nutritional meat quality.

Most research studies that examine supplementation to cattle, range from 0.5% of BW to 1.5% of BW supplementation per head per day. Research by Duckett et al. (2009) used 28 Angus steers in a completely randomized design to examine corn grain supplementation to steers grazing endophyte-free tall fescue. The treatments consisted of pasture only (P), pasture + 0.52% BW corn (PC), pasture + 0.45% soybean hulls and 0.1% BW corn oil (PO), and a high concentrate (85%) diet (C). The 0 to 197 day finishing period resulted in the highest ADG for the C, no difference between PO and PC, which were all greater than the P only treatment. The same treatment differences were also observed for HCW, DP, REA, marbling score, carcass price, and carcass value, meaning C was the greatest with PO and PC not being different but greater than P alone.

Other studies (del Campo et al., 2008 and Latimori et al. 2008) have taken place in Argentina and adjacent countries to examine the effects of different levels of supplementation on animal performance and meat quality. Del Campo et al. (2008) in a study examining beef production systems in Uruguay, used 84 steers randomly assigned to three pasture treatments with increasing levels of grain; 0%, 0.6%, and 1.2% BW. An additional ad libitum (feedlot) diet was also used in the study. Steers were considered finished at a minimum of 6 cm of back fat. Average daily gain increased as rate of supplementation increased, which decreased days to finishing. Interestingly, the intermediate treatments (0.6% and 1.2% BW) had the higher hot carcass weights compared to the 0% BW and feedlot diets, which is in agreement with the work of Vaz

Martins et al., (2003). Steers receiving 1.2% BW had the heaviest pistola cut, or the hindquarter, sirloin with tenderloin. The 1.2% BW treatment also had the heaviest weight of seven boneless cuts compared to the 0% and feedlot diets. They concluded that finishing cattle with supplemental levels of concentrate is a matter of economics and finish time but does not alter quality.

Perhaps of more relevance to our study is the work of Latimori et al. (2008) in the Argentine Pampeana region. Their research included 120 steers of three different genotypes randomly subjected to 4 different diets, 0%, 0.7%, 1.0% BW cracked corn, and feedlot. Steers were finished to an equal carcass endpoint. For the purpose of this section, only the results from Aberdeen Angus are discussed. Average daily gain improved as supplementation rate increased, which is in agreement with del Campo et al. (2008). The feedlot diet had the highest ADG (1.09 kg/d) but was no different than 1.0% BW diet (0.98 kg/d), which was greater than 0.7% BW (0.88 kg/d) and 0% (0.80 kg/d) diets which were not different. There were no diet effects on marbling score, which is in contrast to the review by del Campo et al. (2008). Animal performance was enhanced with increasing energy supplementation, thus many producers in the Pampa region of Argentina are adopting it. This change has lead to questions regarding nutritional quality of the meat, especially for the export market (Latimori et al., 2008)

The work of Latimori et al., (2008) also examined intramuscular fat (IMF) and individual fatty acid (FA) profiles. Overall 1.0% BW supplement had the highest IMF (4.25%) while 0.7% BW (3.58%) and feedlot (3.91)% showed no difference but were both greater than 0% BW (2.89%). Fatty acids were grouped based on saturation.

Saturated FA (14:0 + 16:0 + 18:0) showed did not differ among treatments, and were all approximately 40%. Monunsaturated FA (16:1 + 18:1) were slightly altered by treatment with 1.0% BW being the highest, but not different from 0.7% and feedlot which were greater than 0% BW. There was no difference in polyunsaturated FA (n-3 + n-6)

Their research also separated polyunsaturated FA into omega 3, omega 6, the ratio of the two, and CLA. The 0% BW supplement had the highest concentration of omega 3 FA (2.9%), the two supplementation diets (0.7% and 1.0%) did not differ, but were greater than the feedlot diet. The feedlot diet resulted in the highest concentration of omega 6 FA (8.1%), while the other diets were not different. The large differences in omega 6 and omega 3 led to the highest ratio (14:1) for the feedlot diet, while the other diets were not found to be different. CLA content declined as supplementation increased; 0% and 0.7% BW were no different (0.67% and 0.64% of total FA content), but were greater than 1.0% BW (0.55%) and feedlot (0.28%). Their research concluded that supplementation improved animal performance but the pasture diet and low level of grain supplementation diet generated meat with higher concentrations of CLA and a lower omega 6:omega 3 ratio, thus better nutritional characteristics.

Forage Species

Grasses and legumes have inherent physiological differences. These differences give rise to differences in animal performance and meat quality. The most notable differences between grasses and legumes are in their fiber composition. Fiber is the single largest nutritional component of forages, and is the major factor impacting intake potential and available energy across all forage types. Fibers are non-starch polysaccharides that together form the matrix that is the cell wall. The three rumen-degradable fibers include cellulose, hemicellulose, pectin and their ratios are generally consistent throughout the plant. The other type of fiber in forages is lignin; however, it's quantity varies depending on tissue type (xylum, phloem, mesophyll, etc.) Cellulose is the most complex of the digestible polysaccharides; however, it is slower to be digested than hemicellulose or pectin due to the tightly woven glucose bundles (Hatfield et al. 2008, Hatfield and Weimer 1995). Lignin is not degradable by rumen bacteria and plays a negative role in the total digestibility of forages. Legumes are considered to be more digestible, primarily due to the quantity of pectin in legumes. As plant tissue begins to lignify it binds cellulose and hemicellulose, with less of an impact on pectin. This is particularly true in legumes (Jung and Deetz, 1993). Less pectin is available for digestion in grasses after lignification than in legumes (Jung and Engels, 2002).

Crude protein of legumes is higher than grasses (Schmidt et al., 2013). According to Licitra et al., (1996) the majority of nitrogen in forages is in the form of protein with approximately 5-10% being non-protein nitrogen (NPN) depending on the forage. NPN consists of peptides, amino acids and nitrates. Crude protein tends to decline with maturity for all forage species, as observed by Clapham et al., (2005). Protein that enters the rumen is exposed to microbial fermentation and converted to ammonia; ammonia that is not used for microbial growth is absorbed by the rumen, carried to the liver where it is converted to urea, and then either recycled through saliva or excreted. The majority of protein used by the animal is microbial protein while the protein that bypasses ruminal fermentation is absorbed and used for metabolic activity. Keeping these points in mind, forage with higher protein will generally improve animal performance because forage crude protein is positively correlated with digestible protein (Holter and Reid, 1959). Paulson et al. (2008) found legume haylage to average 20% crude protein; whereas grasses average 13%. This is in agreement with Licitra et al., (1996) who also found alfalfa silage to contain 20.8% CP. In general legume hay, haylage, or fresh forage will have higher CP than grasses.

Research shows (Paulson et al., 2008) that legumes have higher percentages of calcium and magnesium, whereas grasses contain higher percentages of sulfur, phosphorus, and potassium. There is generally no difference in sodium content between legumes and grasses (Schmidt et al, 2013). Overall legumes tend to have higher macro and micronutrient quantities though the relative percentages may differ between plant type (Paulson et al., 2008).

Forages usually have a percent total lipid of between 2 and 4 percent (Clapham et al., 2005; Mir et al, 2006). The main fatty acids in forage are: alpha-linolenic (65%), linoleic (12%), and palmitic (13%) acids. These three fatty acids account for about 90 percent of total FA content (Dewhurst et al., 2001; Clapham et al., 2005; Schmidt et al., 2013). In addition, Dewhurst et al., (2001) and Clapham et al. (2005), in greenhouse experiments, reported a decrease in total FA concentration over time

There can be a high variability in the percentage of the three most common FA among forage type (Clapham et al., 2005). For instance, Clapham et al. (2005) reported significantly higher concentrations of palmitic acid in white clover (WC) compared to grass forages tall fescue (TF) and orchardgrass (OG). In contrast Schmidt et al. (2013) found no difference in palmitic acid concentration between alfalfa (AL) and pearl millet (PM). In addition, Clapham et al. (2005) reported greater proportions of linoleic acid in WC compared to TF and OG but lower levels of α-linolenic. This is in agreement with Schmidt et al. (2013) who reported higher linoleic acid concentrations but lower α-linolenic acid levels for AL compared to PM.

Though some differences exist between forage types, the primary difference in cattle diets is between forages and grains that comprise concentrate diets. In contrast to forages, the primary FA found in corn grain are linoleic (53.0-65.3%), oleic (19.5-30.5%), and palmitic (9.2-12.1%) (Goffman & Bohme, 2001). These values are similar to those reported by Andrae et al. (2001). The higher levels of omega 6 linoleic in corn grain along with a reduction in dietary omega 3 due to less forage intake gives rise to the higher n-6:n-3 observed in grain finished cattle (Duckett et al., 2009).

Legume and Grass Effects on Finishing Beef Cattle

Animal performance and Carcass Quality: It is well established (Fraser et al., 1996, Golding et al., 2011, Dierking et al., 2010) that when all parameters are managed correctly animals grazing legume pasture will tend to gain BW faster than animals grazing grass pasture. This is due to a positive correlation between forage crude protein and digestible protein (Holter and Reid, 1959). Dierking et al. (2010) reported that pastures including legumes provided higher animal ADG than pastures with grass species only. Similarly Fraser et al. (1996) and Golding et al. (2011) found pastures containing legumes resulted in a higher sheep ADG and final carcass weight than sheep grazing grass pastures. Fraser et al. (1996) also found that sheep grazing legumes had a higher fat content at the 12^{th} rib of the longissiums dorsi muscle (LM).

More recent work by Schmidt et al. (2013) reported steers finished on alfalfa as having a higher ADG when compared to those on grasses. In contrast to this study, is the work of Duckett et al. (2013) who reported higher ADG for steers finished on pearl millet (1.61 kg/d) compared to alfalfa (1.15 kg/d) which is in agreement with previous work by Harvey and Burns (1988). Though pearl millet resulted in higher cattle gains, most studies indicate improved animal performance on legumes.

According to Schmidt et al., (2013), forage type impacted DP, FT, MS with a trend to impact USDA quality grade. Legumes (alfalfa and cowpea) had higher DP and FT than grasses (bermudagrass and pearl millet). Cowpea had the greatest marbling score but was not considered different from pearl millet. Cowpea had the highest quality grades. Schmidt et al. (2013) found no differences in SQ or LM fat color with exception to redness (a*) values for the LM where muscle from legume-finished steers had higher a* values than muscle from grass-finished steers. Fewer carcass differences between species were found by Duckett et al. (2013) who reported a higher DP for steers finished on alfalfa compared to those on mixed pasture. There were no LM or SQ color differences between the different forage diets.

Minerals and Vitamins: Schmidt et al. (2013) reported mineral composition of the LM for steers finished on alfalfa, bermudagrass, chicory, cowpea, and pearl millet. Concentrations of P, K, Cu, Mn, Fe, and S did not differ among treatments, whereas steers grazing bermudagrass had higher concentration of Ca, Mg, Zn, and Na compared to all other treatments. These results are interesting, as calcium is typically found in higher concentrations in legume plant tissue than grass tissue. In contrast, Duckett et al. (2013) observed no significant differences in LM mineral concentrations for steers finished on mixed pasture, pearl millet, or alfalfa.

There are a number of papers that report α-tocopherol levels in steaks from grain vs. forage, but few on how specific forage types impact α-tocopherol concentration. Schmidt et al. (2013) reported no significant difference in α-tocopherol among treatments, which is consistent with Duckett et al. (2013) who also reported no difference in α-tocopherol between steers finished on different forage types. Duckett et al. (2013) did however find differences in β-carotene, with steers finished on mixed pasture and pearl millet having higher concentrations compared to those finished on alfalfa.

Fatty Acid Composition and Cholesterol: Overall there are few studies that examine the impacts of dietary forage species on meat lipid profile. Schmidt et al. (2013) and Duckett et al. (2013) both found no differences in total lipid of the LM among different forage diets, and reported similar values ranging from 2.16 to 2.77 g/100g. In terms of individual FA, Schmidt et al. (2013) reported the only significant difference in FA to be for α-linolenic acid. Steers grazing cowpea had the greatest concentration (1.46%) of α-linolenic acid, whereas steers that grazed alfalfa (1.03%) and bermudagrass (0.9%) showed no difference. These results are consistent with Duckett et al. (2013) who reported steers grazing alfalfa (1.32%) had higher concentrations of α-linolenic relative to those grazing mixed pasture (1.17%) or those grazing pearl millet (1.06%). In addition, Duckett et al. (2013) also reported a strong trend for the LM concentration of linoleic acid to be higher in alfalfa (2.85%) compared to mixed pasture (2.59%) or pearl millet (2.27%).

Other work by Kennedy et al. (2006) reported that the only significant difference between beef from steers fed legume vs. grass silage was the n-6:n-3 ratio. Beef from steers fed legume silage had a higher n-6:n-3 ratio (2.93) compared to those fed grass silage (2.76), however, both treatments were in the ≤ 4:1 range recommended by health professionals. Another study by Dierking et al. (2010) concluded that there were no difference in the fatty acid profile of steers finished on tall fescue, tall fescue and red clover, or tall fescue and alfalfa. Though some studies detected minor differences, in general forage type does not strongly impact the fatty acid profile.

Even fewer studies exist on the cholesterol composition of meat from cattle finished on different forages. Duckett et al. (2013) and Schmidt et al. (2013) found no differences in cholesterol of the LM between steers finished on legume or grass forages.

Grain Supplementation Effects on Forage-Fed Beef Cattle Systems

Animal Performance and Carcass Quality: In contrast to grain-finished and forage-finished, grain supplementation is intermediate. Research in Argentina (del Campo et al., 1998; Latimori et al., 2008) has indicated that the optimal level of corn-supplementation to forage-finished steers is 1 percent of body weight per day or less. Based on the work by Pavan et al. (2007) and Crestani et al, (2013) this would be less than half of the animal's total daily dry matter intake (DMI) in supplement. Crestani et al., (2013) found DMI (2.44% of BW) to be similar between forage treatments while Pavan et al., (2007) reported DMI (% of BW) to be 2.79% for pasture, 2.67% for the 0.75 g/kg of BW corn oil treatment, and 2.16% for the 1.5 g/kg of BW corn oil treatment. There was a significant reduction in daily DMI with increasing oil levels (Pavan et al., 2007). This would be expected as lipids contain 2.25x more energy than carbohydrates (Rolls, 1995). Hess et al. (1996) and Elizalde et al., (1998) also reported a decrease in DMI with increasing rate of supplementation.

In addition to these supplementation studies in Argentina and Uruguay, there are a number of other studies (Hess et al, 1996; Elizalde et al, 1998; Horn et al., 2005; Roberts et al, 2009, Corriher et al, 2009) that examined effects of corn supplementation on animal performance and quality. Additional research has examined the impact of different types of supplements such as flaxseed (Nassu et al, 2011 and He et al., 2011), wheat bran (Hess et al, 1996), corn oil (Pavan et al, 2007; Corriher et al, 2009) and dried distillers grains with solubles (Islas and Soto-Navarro, 2010) and their effects on animal performance and carcass quality. In general, these studies found a positive correlation between increasing supplementation and increased animal performance/carcass quality.

Hess et al. (1996) used 216 English crossbred cattle to examine the impacts of different supplements on animal performance. The diets were tall fescue only (CON), wheat bran at 0.34% BW (WBBW), corn grain at 0.34% BW (CORN), and an isocaloric rate of wheat bran at 0.48% BW (WBISO). At the conclusion of the trial, CON steers weighed less than supplemented steers, CORN and WBISO were not different from each other but both greater than WBBW. During the first 48 d of finishing CON had the lowest (0.9 kg/d) ADG, CORN steers (1.19 kg/d) gained more than WBISO (1.14 kg/d), which gained more than WBBW (1.03 kg/d). In the final 42 d of finishing, supplement treatments were not different from each other but all were greater than the CON diet, which was attributed to a decline in forage quality. The total 90 d finishing period ADG reflected the same differences seen in the first 48 d. They concluded that when economically justified isocaloric quantities of wheat bran could be substituted for corn.

Elizalde et al. (1998) used 168 Angus steers (BW = 246.8 kg) to examine the effects of different energy supplementation levels on BW gains and site of nutrient digestion in steers grazing endophyte-infected tall fescue and subsequently finished on concentrate. There were 5 grazing treatments which were tall fescue only (C), 1.4 kg/d cracked corn (CC1), 1.4 kg/d corn gluten feed (CGF1), 2.8 kg/d of cracked corn (CC2) and corn gluten feed (CGF2), and 0.7 kg/d cornstarch with 0.7kg/d corn gluten meal (CS-CGM). During the grazing period, few differences were detected among supplement levels but all supplemented steers had a higher ADG than control steers (0.74 kg/d vs 0.64 kg/d. There were no differences detected for HCW, YG, FT, internal fat or QG. During the finishing phased, different supplementation levels did not impact finishing-performance, which they found to be consistent with previous research. Elizalde et al. (1998) concluded that supplementation to steers grazing spring growth of tall fescue increased ADG, but finishing performance and carcass characteristics were not affected by pre-finishing treatment.

Horn et al. (2005), supplemented steers on wheat pasture with 63% ground sorghum grain and 21% wheat middlings plus monensin. The supplement was selflimiting, and overconsumption was only reported in one group of cattle during the first two years. Overall, daily supplement intake met their target intake range (0.91 to 1.36 kg (as fed) per animal per day). Weight gains were consistently increased by approximately 0.22 kg/d by the supplement. Severity and incidence of bloat was decreased by the use of monensin. In addition, on a per-animal basis, profits were increased by $15-$31 which do not include additional profit as a result of decreased death loss due to bloat. Horn et al., (2005) concluded that monensin-containing supplementation improved animal performance, decreased incidence and severity of bloat, increased stocking rate, and improved profitability, but type and duration of supplementation should be adjusted based on production objectives.

Two additional studies (Roberts et al., 2009 and Corriher et al., 2009) examined differing levels of corn supplementation to steers grazing high quality annual ryegrass pastures. Roberts et al. (2009) used 72 crossbred steers randomly assigned to 6 different diets; no supplement (0.0) to 2.0% of BW (2.0) in increments of 0.5% of BW as well as an ad libitum mixed-ration grain diet. Corn supplementation improved animal performance and Roberts et al. (2009) reported that increasing corn supplementation resulted in a linear decrease in days on feed and a linear increase in ADG, DP, HCW, preliminary YG, final YG, IMF, flavor intensity, and beef flavor. Similarly del Campo et al. (2008) found that corn supplementation increased ADG, carcass weight, and weight of valuable cuts. This is consistent with the findings of Latimori et al. (2007) who also observed a linear increase in ADG with increasing energy supplement. Corriher et al., (2009) used Angus and Angus-crossbred steers to examine the effects of corn (1% BW) and corn + corn oil (0.75% BW) to steers grazing annual ryegrass. They concluded that supplementation improved 112-d ADG (1.65 kg/d vs 1.07 kg/d), which resulted in a significantly higher HCW (321.4 kg vs 288.1 kg). No differences were detected for QG but, in contrast to Roberts et al. (2009), no differences in YG were detected. These findings are consistent with Pavan et al. (2007) who reported supplementation to have no effect on reported marbling or USDA Quality Grade (QG). Overall, energy supplementation at a rate of 1 % of BW or less improved animal performance while having minimal impacts on carcass quality.

A more recent study by Islas et al. (2010) used 16 ruminally-cannulated English-crossbred heifers grazing small-grain pastures to evaluate effects of supplementing different amounts of corn dried distillers grains with solubles (DDGS; 0, 0.2, 0.4, and 0.6% of BW; as-fed basis) on forage intake and digestion. DDGS is a byproduct of ethanol distillation. This process removes the majority of the starch resulting in higher concentrations of lipid and protein (24% CP and 13% fat) compared to regular corn (Islas et al. 2010). In contrast to Pavan et al. (2007), DMI was not significantly reduced with increasing levels of DDGS supplementation even though ether extract of the diet increased (0.37 kg/d to 0.60 kg/d) with increasing levels of supplementation. These results were found to be consistent with previous research. This would be expected because starch as been shown to have detrimental effects on fiber utilization (Sanson et al., 1990). For example, Pordomingo et al., (1991) found 0.2% BW supplementation to steers on pasture increased OM intake and digestibility; whereas, 0.4% and 0.6%

decreased intake and digestibility. Islas et al. (2010) concluded that DDGS can be used to increase lipid intake without impacting forage intake.

An additional study by He et al. (2011) examined the effects of feeding flaxseed to cows on forage and barley grain or silage and barley grain diets. The primary focus of this paper was on α-linolenic acid and biohydrogenation intermediates of SQ fat, but animal performance was reported as well. As expected there was a significant increase in final BW for cows on silage compared to those on hay (770 kg vs 705 kg) which was a result of higher ADG for cows on silage (1.87 kg/d) compared to hay (1.16 kg/d). More importantly, there was a significant impact with the incorporation of flaxseed into the ration. Cows consuming hay that was supplemented with flaxseed and barley as compared to barley alone had an increased ADG (1.40 kg/d vs 1.07 kg/d) and final BW (739 kg vs 705 kg). Feeding flaxseed also resulted in a 25% increase in feed efficiency (kg of BW gain/ kg of DM fed) for cows on hay, 0.102 with flaxseed and 0.077 without flaxseed. He et al. (2011) concluded that the inclusion of 15% flaxseed in hay- or silage-based diets increased ADG and productivity of cull cows.

Based on the research above, it can be concluded that high-energy supplementation improves animal performance with a tendency to improve carcass quality depending on study reviewed.

Fatty Acid Composition and Cholesterol: There were no studies found that examined how varying levels of supplementation impacted cholesterol. The research of Duckett et al. (2009) reported no difference in cholesterol between pasture and feedlot finished beef suggesting that supplementation would likely have the same outcome.

In addition to the papers from Argentina, there are other studies (Baublits et al., 2006; Duckett et al., 2009; Corriher, et al. 2009; Nassu et al., 2011; He et al., 2011) that examined the effects of different types of supplementation on the fatty acid composition. Baublits et al. (2006), and Duckett et al., (2009), Corriher et al. (2009) reported a greater total lipid for supplemented cattle; whereas, the studies (Nassu et al., 2011; He et al., 2011) that examined flaxseed supplementation did not find any increase in total lipid.

When comparing ryegrass pasture to ryegrass with corn supplementation at 1% of BW, Corriher et al. (2009) reported no differences in FA composition. These results are consistent with Schor et al. (2007), with exception to CLA, Schor et al. (2007) reported CLA *c*9*t*11 to be in a lower concentration (0.65% vs 0.8%) in supplemented steers. This is consistent with Latimori et al. (2007), who examined Argentine beef from pasture only, 0.7% BW energy supplementation, and 1.0% BW energy supplementation and also concluded no major differences in FA composition with exception to CLA. Pasture only and 0.7% BW showed no difference whereas 1.0% BW showed a reduction in CLA (0.67 vs 0.55 g/100g) compared to pasture only.

Baublits et al. (2006) compared British x Continental steers and heifers (n=108) on tall fescue pasture, tall fescue pasture with soyhulls (1% of BW), and orchardgrass with soyhulls (1% of BW). Beef from the two supplemented treatments had decreased PUFA and omega-3 FA compared to the pasture alone. Although supplementation increased the n-6:n-3 ratio, all treatments had ratios below 4:1. The increase in omega-3 was a result of increased levels of EPA, DPA, and DHA, which were all higher in non-supplemented steers (1.26%, 1.52%, 0.15%, respectively). There were no differences in

SFA between treatments, and interestingly, the P:S was remarkable high compared to all other studies reviewed. Pasture without supplementation was the highest (0.35), followed by orchardgrass (0.30), and tall fescue (0.23). Also in contrast to previously reported studies (Schor et al., 2007; and Latimori et al., 2007, Corriher et al., 2009), there were no differences in CLA *c*9*t*11 observed, suggesting that supplementing soyhulls does not have the same impact on CLA as corn does.

Duckett et al. (2009) used 28 Angus steers to examine how 4 different diets impact SQ fatty acid content. Treatments were high concentrate (CONC), tall fescue with corn grain supplement (PC; 0.52% of BW), tall-fescue with corn oil and soyhulls (PO; 0.10% of BW corn oil plus 0.45% of BW soybean hulls), and a tall fescue control (PA). For the purpose of this section, CONC will not be discussed. Total SFA was greater in PA (34.38%) and PO (32.05%) as compared to PA (27.25%). This was in part due to increased levels of myristic (C14:0) and palmitic acid (C16:0). Stearic acid was higher for PO (14.84%) compared to PC (11.97%) and PA (10.98%). Total MUFA was greatest for PC (29.13%), and no difference was observed between PO (25.64%) and PA (21.97%). Corn oil supplementation had a 1.2% and 1.7% increase in *trans*-11 vaccenic acid compared to PA and PC respectively. Oil supplementation also had a similar effect on CLA *c*9*t*11of the LM and increased concentrations by 54% and 58% compared to PA and PC, respectively. Omega-6 FA concentration was highest for PO (1.23%), which was greater than PC (0.62%), which was greater than PA (0.34%). There were no differences detected for omega-3 levels, and though n-6:n-3 was highest for PO (2.81), all values were less than the ideal ratio of 4:1.

With the goal of increasing dietary omega-3 FA intake for improved human health, additional studies (Nassu et al., 2011; He et al., 2011) have examined how flaxseed supplementation impacts lipid profile of beef. Though different authors, both of these studies (Nassu et al., 2011; He et al., 2011) are a result of the same experiment. Nassu et al. (2011) reported the entire FA profile for muscle and SQ fat, whereas He et al. (2011) focused on α-linolenic acid and biohydrogenation intermediates in subcutaneous fat. Sixty-four British x Continental non-lactating, non-pregnant cows were randomly assigned to four diets, all of which contained 50% concentrate and 50% forage. The treatments were a hay control (HC), hay with flaxseed (HF), silage control (SC), and silage with flaxseed (SF). Both flaxseed and hay feeding increased concentrations of α-linoleic acid in the LM and backfat. There was a significant forage type x flaxseed interaction observed, which indicated feeding hay with flaxseed increases total CLA and total *trans*-11 vaccenic compared to all other treatments. Supplementing flaxseed to cows on hay and barley reduced SFA (40.3% vs 43.13%), increased total MUFA (49.18% vs 48.78%), and increased total PUFA (5.58% vs 5.35%). The response in PUFA was attributed to an increase in omega 3 (1.89% vs 1.19%) and not omega 6, where no differences was observed. The increase in omega 3 decreased n-6:n-3 ratio, (1.78% vs 3.32%), though both values are within the recommended range. Both papers (Nassu et al., 2011; He et al., 2011) concluded feeding flaxseed increases most α-linolenic biohydrogenation intermediates. The predominant intermediates observed were CLA *c*9*t*11 and *trans*-11 vaccenic acid

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CHAPTER 2

EFFECT OF FORAGE TYPE AND CORN SUPPLEMENTATION ON ANIMAL PERFORMANCE AND MEAT QUALITY

Abstract

Angus x Hereford steers (n = 32) were used in a 2-yr study to examine forage type (legume species, LG: *Medicago sativa* and *Glycine max*, vs. grass species, GR: *Loliium arundinaceum* and *Sorghum bicolor*) and daily corn supplementation (none, NS, vs. 0.75% BW of corn grain, CS) on animal performance and carcass quality. Steers grazed (May-August) for a total of 98 d and 105 d in 2011 and 2012 respectively. Upon completion of the finishing period, steers were slaughtered and carcass data were collected. Data were analyzed in a mixed model using a 2x2 factorial arrangement of treatments with forage type, corn supplementation, and forage type x corn supplementation in the model. Steer was the experimental unit and year was considered a random effect. Corn supplementation (CS) increased ($P < 0.05$) average daily gain (ADG), hot carcass weight (HCW), dressing percentage (DP) and tended ($P < 0.06$) to increase fat thickness at the 12th rib (FT). CS also increased ($P < 0.05$) yield grade (YG) and there was a trend to increase ($P < 0.07$) quality grade (QG). In terms of forage, LG increased ($P < 0.05$) DP and HCW, with a tendency to increase ADG ($P < 0.06$) when compared to GR. CS resulted in lower ($P < 0.05$) concentrations of CLA c9t11 and n-3 fatty acid (FA). Lower n-3 FA resulted in a higher ($P < 0.05$) n-6:n-3 ratio (3.1 vs. 2.4), though both ratios are still considered acceptable for human health. Feeding GR increased ($P < 0.05$) saturated FA which was impacted by a greater ($P < 0.05$)

concentration of stearic acid (C18:0). LG forage resulted in higher ($P < 0.05$) calcium and a strong trend for higher ($P < 0.054$) potassium. Alpha-tocopherol and beta-carotene were impacted ($P < 0.05$) by supplementation and forage type but were both in a healthy range. Tenderness was only affected ($P < 0.05$) by postmortem aging.

Introduction

Forage-finished beef remains a niche market in the U.S., but it continues to grow each year in terms of consumer demand and producer interest (Fisk et al., 2012). This is related to perceived benefits to human health (Duckett et al., 2009) and the environment (Sithyphone et al., 2011). Forage-finished beef has been shown to contain less fat, an altered fatty acid profile, and increased amounts of B-vitamins and antioxidants (Duckett et al., 2009). Producers in the Southeast do not traditionally finish cattle because of the variable forage-quality throughout the grazing season and the high cost of grain. Historically, during times of high grain prices, there is a renewed interest in forage-finishing (Bowling et al., 1977). With the increased costs of finishing cattle on grain diets and a growing consumer interest in forage-finished beef, producers are seeking ways to finish their own cattle. They are doing so by supplementing their permanent pasture with high-quality winter and summer annuals or by incorporating a high-energy supplement during the finishing phase of production. Studies indicate that pastures containing legumes have improved animal performance and in some cases carcass quality (Dierking et al., 2010; Golding et al., 2011). Daily corn supplementation (≤ 1%BW) can also improve performance and carcass quality (Elizalde et al., 1998; Roberts et al., 2009) of grazing cattle, while not significantly impacting the fatty acid profile (Latimori et al., 2008). Supplementing steers on pasture may also allow increased stocking rate (Horn et al., 2005; Pavan et al., 2008). The effects of including a high-energy supplement to cattle finishing on pasture raises questions about human-health. Overall, the studies that examined the impacts of daily grain supplementation on meat quality found only subtle differences between the treatments (Corriher et al., 2009; Del Campo et al., 2008; Latimori et al., 2007). The objective of this study was to examine the effect of all legume or all grass forage sequences with or without daily corn supplementation on animal performance, carcass characteristics, and meat quality.

Materials and Methods

Forage Establishment. The 2011 grazing season utilized (September 2006) 2 ha paddock of alfalfa (*Medicago sativa,* Alfagraze 600R) and 2 two-year old paddoks of MaxQ novel-endophyte tall fescue (*Lolium arundinaceum*). In May of 2011, three 2 ha paddocks of soybeans (Large Lad RR) and three 2 ha paddocks of hybrid sudangrass (Promax) were drilled into a killed seed bed at a rate of 81 kg/ha and 25 kg/ha respectively. In October 2011, two additional 2 ha paddocks of Alfagraze 600RR were drilled into a killed seedbed at a rate of 23 kg/ha for the 2012 grazing season. During the 2012 grazing season, the same Max Q tall fescue pastures (4 ha) from 2011 were used again. In May of 2012, soybean and sudangrass were planted as they had been the previous year. Soils were tested at the Clemson Agriculture Service Lab and fertilized according to soil test recommendations.

Forage Sample Collection. During the experiment, forage samples were taken at, approximately 14-day intervals when animals were rotated to fresh paddocks. Forage allowance samples consisted of 10 random quadrat samples (366 cm^2) taken before and after grazing. Samples were dried at 95º C and weighed. Forage allowance was calculated according to Sollenberger et al. (2005). Diet samples were taken before steers grazed a new paddock. Diet samples for proximate and fatty acid analysis were frozen at -20ºC and subsequently freeze-dried and ground in a Wiley mill to pass a 2-mm screen.

Forage Proximate Composition. Duplicate freeze-dried samples for each diet were analyzed at the Clemson University Agriculture Service Laboratory for mineral composition and CP. Minerals were analyzed using inductively-coupled plasma mass spectorometry (ICP). Minerals were expressed in ppm or percent of sample on a dry basis. Duplicate samples were weighed out (0.5 g) and placed in F57 filter bags to analyze for percent NDF and ADF. Bags where then placed in an ANKOM Fiber Analyzer with the appropriate NDF and ADF solutions and analyzed according to Van Soest et al. (1991). Crude protein was analyzed using combustion on a Leco FB528 analyzer (Leco Corp., St. Joesph, MI) (AOAC, 1990). Total lipids were extracted using an ANKOM fat extractor (XT-15, ANKOM, Macedon NY). Total ash content was determined by ashing at 600ºC for 8 h (AOAC, 2000). All proximate analysis were corrected to a 100% DM basis using duplicate forage samples dried at 100ºC for 24h.

Forage Fatty Acid Composition. Lipid extracts containing approximately 10mg of total lipids were transmethylated according to the method of Park and Goins (1994). An Agilent 6850 gas chromatograph equipped with an automatic injector (Agilent, Santa Clara, CA) was used for detection and separations were accomplished using a 100-m

SP2560 (Supelco, Bellefonte, PA) capillary column (0.25 mm i.d and 0.20 µm fil thickness). Column oven temperature increased from 150ºC to 160ºC at 1ºC per min, from 160 to 167ºC at 0.2ºC per min, from 167 to 225ºC at 1.5ºC per min, and then held at 225ºC for 16 min. The injector and detector were maintained 250ºC. Sample injection volume was 1 µL. Hydrogen was the carrier gas at a flow rate of 1 mL per min. Individual fatty acids were identified using comparison of retention times with known standards (Sigma, ST. Louis, MO; Supelco, Matreya, Pleasant Gap, PA). Fatty acids were quantitated with an incorporated internal standard, methyl tricosanoate (23:0) acid, into each sample during methylation and expressed as a percentage of total fatty acids detected on a 100% DM basis.

Animals and Feeding. All procedures involving animals were approved by the Clemson Animal Care and Use Committee. Angus x Hereford steers were used in a 2 year study (n=16/year) to evaluate the effects of forage type (legume species [LG]: alfalfa and soybeans vs. grass species [GR]: non-toxic tall fescue and sudangrass) and daily corn supplementation (none [NS] vs. 0.75 % of body weight corn grain [CS]) on animal performance and meat quality. Prior to the trial, all steers were weaned and backgrounded on winter cereal rye (*Lolium multiflorum* Lam.) pasture followed by endophyte-infected tall fescue (*Lolium arundinaceum*, MaxQ, Pennington Seed Co.). During this period, trial steers were trained to Calan gate feeders (American Calan Inc., Northwood, NH).

Each year upon completion of the background phase steers were stratified by weight and then randomly assigned to a treatment. The four treatments were legume with corn supplementation (LG:CS), legume with no corn supplementation (LG:NS), grass with corn supplementation (GR:CS), and grass with no supplementation (GR:NS). Each forage type was replicated with each replicate containing 4 steers, two supplemented and two not supplemented. No anabolic implants were used in this experiment.

At the beginning of the trial, steers were weighed two consecutive days and the starting weight was the average of the two days. Steers were then weighed every 28 days for the duration of the experiment. The year 1 finishing period was 98 days and year 2 was 105 and steers were moved approximately every 14 days. Overall stocking rate was 1 hd/ha with individual paddock stocking density at 2 hd/ha. All steers grazed the perennial forage for each forage type prior to grazing the annual: alfalfa (*Medicago sativa* L.) to soybean (*Glycine max* L.) and tall fescue (*Lolium arundinacea* Schreb.) to sudangrass (*Sorghum bicolor* L.) (Table 2.3). The CS ration consisted of cracked corn fed at 0.75% BW + 150mg of monensin (Table 2.4). Corn supplementation amounts were adjusted at each 28 day weigh period according to individual steer weight. Steers were given free choice access to a loose mineral mixture (Table 2.1) and steers grazing legumes also had access to Sweetlix Bloat Block (Table 2.2). Upon completion of the finishing period steers were fasted overnight and weighed prior to transport to the meat packing plant.

Meat Sample Collection. Animals were transported (130km) to a commercial packing plant and slaughtered. At 24 h postmortem carcass characteristics including maturity, fat thickness at the 12th rib, 12th-rib LM area, KPH, marbling score, USDA quality grade and yield grade were determined. The entire rib section (IMPS107) was removed from the left side and transported to Clemson, SC for fabrication. At 48 h postmortem, the entire *longissiums dorsi* muscle (LM) was removed from the rib. The LM was cut into individual 2.5 cm thick steaks. Five steaks were randomly assigned to postmortem aging treatments and an additional steak from the posterior end of rib (12^{th} rib) was removed for proximate and fatty acid analysis.

Instrumental Color. Color measurements were recorded for lightness (L*), redness (a*), and yellowness (b*) using a Minolta chromameter (CR-310, Minolta Inc., Osaka, Japan) with a 50-mm- diameter measurement area using a D65 illuminant, which was calibrated using the white ceramic disk provided by the manufacturer. The L* value represents lightness on a scale of 0 (black) to 100 (white). The a* value represents redness, where positive numbers are red and negative numbers are green. The b* value represents yellowness, where positive values are yellow and negative values are blue. Color readings were determined at 2 d postmortem on the exposed LM at the posterior (12_{th} rib) of the rib and s.c. fat covering the posterior rib. Values were recorded from three locations of exposed lean and s.c. fat to obtain a representative reading.

Proximate Composition. Moisture content was determined by weight loss after drying at 100ºC for 24 h. Ground samples were then, frozen, lyophilized, and ground for all additional analysis. Duplicate samples of the LM were analyzed at the Clemson University Agriculture Service Laboratory for mineral composition and N. Minerals were analyzed using inductively-coupled plasma mass spectrometry (ICP). Minerals were expressed in ppm or percent of sample on a wet basis. Nitrogen content was analyzed using a Leco FB528 analyzer (Leco Corp., St. Joesph, MI; AOAC, 1990) and CP was calculated by multiplying by 6.25. Total lipids were extracted in duplicate from LM using

Ankom fat extractor with hexane (XT-15; Ankom). Total ash content was determined by ashing at 600ºC for 8 h (AOAC, 2000).

Cholesterol and Fat Soluble Vitamins. Cholesterol content of LM was determined according to Du and Ahn (2002) and quantified by incorporating an internal standard, stigmasterol, into each sample. Concentrations of fat soluble vitamins (α-tocopherol and ß-carotene) in the LM were determined using the procedure outlined in Lee et al. (2005)

Tenderness. The five LM steaks assigned to aging treatments (2, 4, 7, 14 and 28) were vacuum packaged and stored at 4ºC until being frozen at -20ºC. Steaks were thawed at 4ºC for approximately 12 h before being cooked to an internal temperature of 71ºC on an electric grill. After cooking, degree of doneness was assessed and steaks were allowed to cool to room temperature before 1.27 cm cores (6 per steak) were removed. Cores were sheared perpendicular to the muscle fibers using a Warner-Barztler shear force machine (Standard Shear Model 2000 D, G-R Manufacturing Co; Manhattan, Kansas).

Fatty Acid Composition. Samples of the LM containing approximately 12 mg lipid were transmethylated according to the method of Park and Goins (1994). An Agilent 6850 gas chromatograph equipped with an automatic injector (Agilent, Santa Clara, CA) was used for detection and separations were accomplished using a 100-m SP2560 (Supelco, Bellefonte, PA) capillary column (0.25 mm i.d and 0.20 μm fil thickness). Column oven temperature increased from 150ºC to 160ºC at 1ºC per min, from 160 to 167ºC at 0.2ºC per min, from 167 to 225ºC at 1.5ºC per min, and then held at 225ºC for 16 min. The injector and detectore were maintained 250ºC. Sample injection volume was 1 μL. Hydrogen was the carrier gas at a flow rate of 1 mL per min. Individual fatty acids were identified comparison of retention times with standards (Sigma, ST. Louis, MO; Supelco, Matreya, Pleasant Gap, PA). Fatty acids were quantitated with an incorporated internal standard, methyl tricosanoate acid (C23:0), into each sample during methylation and expressed as a percentage of total fatty acids on a wet basis.

Statistical Analysis. All data were analyzed using a 2x2 factorial arrangement of treatments in a completely randomized design using Proc GLM of SAS (Cary, NC). Significance was determined at $P < 0.05$ and differences of $P > 0.05$ to $P \leq 0.10$ were considered as trends. If the two-way ANOVA was found significant, LS means were separated and analyzed using a Fisher's LSD. If the overall *F-test* for the interaction was not found significant only the main effects were analyzed. If the *F-test* for the interaction was found significant, then LS means for the simple effects were separated and analyzed. All data with exception to Warner-Bratzler shear force and forage data were analyzed using the following 2x2 factorial design:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \gamma_k + \varepsilon_{ijk}$$

where Y_{ij} was the response variable for a steer randomly assigned to a forage type α_i (LG or GR) and a supplementation treatment β_j (NS or CS). The $\alpha\beta_{ij}$ was for the forage type by supplementation interaction, or the four simple effects. The μ was overall mean. The random terms were year (γ_k) and residual error (ε_{ijk}). Each supplemented steer was fed individually using Calan gates, thus steer was considered the experimental unit. The Warner-Bratzler shear force data were analyzed using the same 2x2 factorial arrangement of treatments in a completely randomized design, but with the addition of 5 different aging treatments (2, 4, 7, 14, and 28 d) the model was expanded to include the repeated measures based on days aged:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + S(\alpha_i\beta_j) + \delta_l + \alpha_i\delta_l + \beta_j\delta_l + \alpha_i\beta_j\delta_l + \varsigma_m + \gamma_k + \varepsilon_{ijk}$$

where Y_{ij} was the response variable for a steer randomly assigned to a forage type α_i (LG or GR) and a supplementation treatment β_j (NS or CS). The $\alpha\beta_{ij}$ was for the forage type by supplementation interaction. In this model, error was further allocated into the subject within forage type by supplementation variation [$S(\alpha_i\beta_j)$] to test for between subject variation. The within subject variables included days aged (δ_l), forage type by days aged interaction ($\alpha_i\delta_l$), supplementation by days aged interaction ($\beta_j\delta_l$), and forage type by supplementation by days aged interaction ($\alpha_i\beta_j\delta_l$). The μ was overall mean. Degree of doneness was assessed for each steak and was used as a covariate (ς_m). The random terms were year (γ_k) and residual error (ε_{ijk}). In addition to animal data, the legume and grass forage sequences were analyzed using a 2x2 factorial arrangement of treatments in completely randomized design. Methods for determining significance were the same as above. The forage sequence model was:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \gamma_k + R(\alpha_{i,}\beta_j) + \varepsilon_{ijk}$$

where Y_{ij} was the response variable for a forage sample from either a legume or grass forage sequence α_i over four periods (P1-P4) β_j. The interaction was forage by period ($\alpha_i\delta_l$). The μ was the overall mean. The random variables were year (2012 and 2013) γ_k, replicate (paddock A or B) nested in forage and year $R(\alpha_{i,}\beta_j)$, and residual error (ε_{ijk}).

Results and Discussion

Forage Chemical Composition. Average monthly precipitation during 2011 and 2012 is shown in Figure 2.1. The 30-year rainfall average for February to August is 72.9 cm. During the 2011 grazing season, rainfall totaled 49.5 cm or 23.4 cm below the 30-year average. During the 2012 grazing season, rainfall totaled 56.0 cm or 16.9 cm below the 30-year average. In 2011, precipitation was higher during February and March compared to 2012, whereas in 2012, precipitation was greater during April to August.

Throughout the 2012 grazing season, forage allowance was higher ($P < 0.05$) for steers grazing legumes compared to those grazing grass (91.9 vs 77.2 kg DM/ 100 kg BW); however, both values are much lower than those reported in previous studies (Horn et al., 1999; Fieser et al., 2006). This could be related to the below average rainfall seen throughout the study; however, it is difficult to compare our results to Horn et al. (1999) and Fieser et al. (2006) because these studies were conducted on winter wheat pastures, from September to March, in Oklahoma; a very different scenario from ours at Clemson, during the late spring and summer, in the South Carolina. The higher forage allowance reported in Horn et al. (2006) and Fieser et al. (2006) are more than likely attributed to the fact that the winter pastures were later harvested for grain, and a lighter stocking rate was needed to ensure a successful grain crop. Despite our lower forage allowance values, the daily gains seen in our study were similar to others (Horn et al., 1999; Fieser et al., 2006) who reported higher forage allowances, possibly due to more efficient forage utilization in our study.

Mineral composition for the legume and grass forages are presented in Table 2.3. There were no forage effects ($P > 0.05$) detected for P, K, Mg, Zn, or Cu. Grasses had higher concentrations ($P < 0.05$) of manganese and iron compared to legume but legume had higher ($P < 0.05$) concentrations of sulfur compared to grass. These findings are in contrast with Paulson et al. (2008) who found grass hay to have higher concentrations of sulfur and potassium compared to legume hay. The differences between studies could be attributed to differences in fertilization, harvesting, and the differences between hay and fresh forage. In our study there was a tendency for grass to have higher concentrations of potassium compared to legume (2.26 vs 1.96%). Legume contained more calcium compared to grass (1.03% and 0.45%, $P < 0.001$). In general, these findings are similar to Schmidt et al. (2013) who reported cowpea and alfalfa to have higher concentrations of Ca when compared to bermudagrass and pearl millet. Paulson et al. (2008) also found legumes to have higher percentages of calcium compared to grasses.

There were no period effects detected for K, S, Zn, Cu, Mn, or Fe. There where period effects detected for concentrations P, Ca, Mg, and Na all of which declined over the grazing season, with exception to Mg which showed a slight increase. Similarly, Grings et al. (1996) also reported a decline in plant-tissue P, Ca, Mg, and Na from April to September. The decline in minerals over time could be attributed to plant growth and maturity as well as climatic differences throughout the different phonological stages.

Forage proximate composition is presented in table 2.3. There were no forage effects detected for ADF, lipid, or ash. Forage NDF, was much lower for legume compared to grass (29.5% vs 51.2%; $P < 0.001$). This was expected as legumes often contain lower NDF concentrations than grasses (Buxton et al., 1997; Schmidt et al., 2013). As fiber concentration decreases, so does the proportion of fiber to cell solubles, which results in higher digestibility (Buxton et al., 1997) and the increased animal performance observed for grazing legumes compared to grasses (Dierking et al., 2010; Golding et al., 2011; Schmidt et al. 2013). Legumes had higher CP than grasses (24% vs 19%, $P < 0.002$). It is well documented that legumes have more CP than grasses (Licitra et al, 1996; Paulson et al., 2008, Schmidt et al., 2013).

Concentrations of fatty acids (FA) are presented in table 2.3. Linolenic (C18:3), linoleic (C18:2), and palmitic acid (C16) comprised approximately 95% of total FA. These results are in agreement with Clapham et al. (2005) and Schmidt et al. (2013).

There were significant ($P < 0.05$) forage by period interactions for myristic (C14:0) and stearic (C18:0) which are shown in 2.3. For the first three periods legume had a higher concentration of myristic, but in the fourth period legumes and grasses did not differ, 0.43% and 0.46% respectively. Legumes had higher concentrations of stearic acid compared to grass throughout the four periods (5.66% vs 3.65%); however, the interaction between legume and grass that was detected was because grass showed little difference in stearic acid over the four periods, whereas the concentration of stearic acid in legume was lower in period 1 and 2 than 3 and 4.

Legumes had a higher concentration ($P < 0.05$) of palmitic acid (C16:0) compared to grasses (22.8% vs 17.0%). These findings are similar to Schmidt et al. (2013) who found cowpea to have the highest concentration of palmitic acid compared to two grass species. This is in contrast to Clapham et al. (2005) who reported no differences in palmitic acid between legumes and grasses. Legumes had a higher concentration ($P < 0.05$) of oleic compared to grasses (3.31% vs 2.26%). For all forages, oleic acid was highest ($P < 0.05$) during period 1 compared to period 2 and 3 but did not differ ($P > 0.05$) from period 4. The decline in forage-fatty acid seen over time could be attributed to the shift between vegetative and reproductive growth stages. As stem increases during the reproductive stage, leaf proportion decreases, other metabolites (fiber) increase, and FA concentrations decrease through dilution effects. Clapham et al. (2005) also reported similar declines in forage FA over time. Linolenic acid was the most abundant ($P < 0.05$) FA in all forages but was almost 15 percentage units higher ($P < 0.05$) in grass (64% vs 50%). Schimdt et al. (2013) also reported pearl millet to have a higher concentration of linolenic acid compared to cowpea or alfalfa. Interestingly, linolenic acid increased over the trial, which may be attributed to the change in forage type during the trial when steers were moved from the perennial to the annual forages.

Live Animal Performance and Carcass Characteristics. Animal performance and carcass characteristics are presented in Table 2.5. All interactions were non-significant ($P > 0.05$). Forage type did not alter ($P > 0.05$) final weight; however there was a tendency ($P < 0.07$) for steers grazing LG to have an improved ADG compared to GR (0.81 kg vs 0.72 kg). These results are similar to others (Dierking et al., 2010; Golding et al., 2011; Schmidt et al., 2013) who all reported grazing legumes resulted in higher animal gains compared to grasses. Steers grazing legumes had a greater ($P < 0.05$) hot carcass weight (HCW) and greater dressing percentage (DP) compared to steers grazing GR. Similarly, Schmidt et al. (2013) reported an increased DP for legume (alfalfa and cowpea) compared to grasses (bermudagrass and pearl millet); however, Duckett et al. (2013) found no difference in DP between alfalfa and pearl millet, which were both greater than mixed grass pastures. Forage type had no impact on fat thickness at the 12th rib (FT), kidney, pelvic, heartfat (KPH), USDA yield grade, or USDA quality grade, which differs from Schmidt et al. (2013) who reported cowpea to have an increased FT compared to grasses as well as a tendency to have a higher USDA quality grade.

Steers receiving CS tended ($P < 0.10$) to finish at heavier weights compared to NS steers. This resulted from steers on CS having higher ($P < 0.01$) ADG compared to steers on NS, which is in agreement with other studies (Hess et al., 1996; Elizalde et al., 1998; Horn et al., 2005; Roberts et al., 2009; Corriher et al., 2009). This could possibly be attributed to the differences in energy density between diets and their subsequent impact on microbial fermentation in the rumen (Kung et al., 1992). The increase in energy would favor a more efficient energy to protein ratio. In addition, CS would be expected to raise the acetate to propionate ratio of the rumen and ultimately increase the amount of glucose that reaches the small intestine, both of which would increase the amount of gluconeogenic precursors, thus stimulating fat synthesis. As a result, steers receiving CS had a greater ($P < 0.05$) HCW, DP, and FT with a tendency ($P < 0.09$) to have increased amounts of KPH. Carcasses from NS steers had lower ($P < 0.05$) yield grades compared to CS. Supplemented steers also tended ($P < 0.07$) to have a better USDA quality grade compared to NS.

Color values for the LM and SQ are located in Table 2.6. Overall, there were no differences (*P* > 0.05) among forage type or supplementation treatments for LM L*, a*, or SQ L* and a*. Subcutaneous fat from steers on CS was yellower (*P* < 0.05) than NS, though differences could not be detected with the eye. This may have resulted from increased levels of β-carotene (*P* < 0.05) seen in supplemented steers grazing grass.

Warner-Bratzler shear force (WBS) scores are presented in Figure 2.4. Dietary treatments did not alter (*P* > 0.05) tenderness. Postmortem aging was the only treatment to alter (*P* < 0.001) tenderness. Warner Bratzler shear force decreased (*P* < 0.05) with postmortem aging with 7 and 14 days being lower than 2 and 4 days, which were higher than day 28. There was a significant (*P* < 0.05) aging period by corn supplementation interaction (Figure 2.5). The LM from steers finished with CS reported lower shear force scores compared to NS with 2 days of postmortem aging (3.25 kg vs 3.40 kg), but higher shear force scores compared to NS after 4 days of postmortem aging (3.41 kg vs 2.9 kg). According to the work of Miller et al. (2001), a steak is guaranteed to be tender, from a consumer acceptability standpoint, if it requires ≤3.0 kg of force to shear. Steaks in our study had WBS values lower than 3 kg by 7 days of postmortem aging. Baublits et al. (2006) examined shear force from cattle finished on a pasture control vs pasture with soyhull supplementation and found no difference between treatments, which is in agreement with Latimori et al. (2008) who found no difference in shear force between steers on pasture with different levels of corn grain. The shear force scores from our study support previous research and it can be concluded that diet had little impact on tenderness.

Proximate composition of the LM did not differ (*P* > 0.05) between forage types (Table 2.7). Duckett et al. (2013) also reported no difference in LM proximate composition of steers finished on different forages. Interactions between forage type and CS were non-significant. Moisture content tended (*P* < 0.06) to be higher in steers on NS compared to CS. This is consistent with previous research (Baublits et al., 2006; Roberts et al., 2009) suggesting that as total lipid of the LM increases moisture subsequently decreases. Interestingly, there were no differences in lipid detected between CS and NS. Other studies have reported no differences in total lipid of the LM between supplemented (approximately 0.6% of LW) and non-supplemented steers (Elizalde et al., 1998; Del Campo, 2008) suggesting that supplementation rates of 0.75% of BW or less do not alter total lipid of the LM. The LM from steers grazing legume had a higher (*P* < 0.03) concentrations of calcium (9.02 vs 7.17) and lower levels (*P* < 0.05) of potassium (348.4 vs 356.7). This would be expected, as legume forages have higher a concentration of calcium (Table 2.3). Other minerals (Mg, Na, Zn) were not altered (*P* > 0.05) by forage type or CS. Supplementation decreased (*P* < 0.05) calcium concentration in LM muscle.

Cholesterol concentartions of the LM are presented in figure 2.6. There were no treatment main effects, however there was a significant (*P* < 0.05) forage type x supplementation interaction (Figure 2.6). Cholesterol content was higher (*P* < 0.017) in CS-LG than NS-LG, whereas supplementation had no affect on GR. The range of values from our study (49-56 mg/100g) are similar to the previous work of Duckett et al. (2009) who concluded no difference in total cholesterol between concentrate or pasture finished steers (56.3 vs 52.3 mg/100g). An additional study by Andrae et al. (2001) examined the effects of high-oil corn vs regular corn in finishing diets on meat quality and carcass characteristics. They too found no difference between treatments and the cholesterol values of the LM from their study (55.8-56.7 mg/100g) which are similar to those from Schmidt et al. (2013) who also reported no differences in cholesterol between treatments. Though LG-NS was lower in cholesterol than all other treatments, differences may be too small to be considered biologically significant, especially when considering the small role dietary cholesterol plays, compared to fats, in serum cholesterol levels.

The results for α-tocopherol concentration of the LM are also presented in table 2.7 and there was a significant ($P < 0.01$) main effect of forage type. The LM from steers grazing GR had higher concentrations of α-tocopherol (396.16 vs 249.8 μg/100g) compared to steers grazing LG. These findings are in contrast to the work of Schmidt et al. (2013) who reported forage type to have no impact on α-tocopherol concentration of the LM. There was a significant ($P < 0.01$) forage type x supplementation interaction for β-carotene (Figure 2.7). Corn supplementation to steers grazing GR increased ($P < 0.05$) β-carotene compared to NS steers grazing GR (19.04 vs 12.98 μg/100g), while steers grazing LG were not between CS or NS. Overall the β-carotene values reported from this study are lower than earlier work in our lab by Duckett et al. (2009) whose values ranged from 28.53 to 43.88 μg/100g.

Fatty acid (FA) composition as a percent of the total FA profile of the LM is presented in Table 2.9. Finishing on GR increased ($P < 0.05$) stearic acid (C18:0) and total SFA concentrations in LM compared to LG. Schmidt et al. (2013) reported higher values for stearic acid in bermudagrass compared to alfalfa, however bermudagrass was not different than cowpea. Others (Kennedy et al., 2009; Schmidt et al., 2013; and Duckett et al., 2013) also found no differences in total SFA concentration between forage treatments. Trans-9 octadecenoic acid (C18:1 trans-9) was also higher for GR than LG. Schmidt et al. (2013) reported higher concentrations of Trans-9 octadecenoic for steers finished on bermudagrass and pearl millet compared to alfalfa while Duckett et al. (2013) found no differences between pearl millet and alfalfa. Other FA were not affected by forage type ($P > 0.05$). All interactions between forage type and CS were non-significant ($P > 0.05$) with the exception of trans-11 vaccenic acid (Figure 2.8) and linolenic acid (Figure 2.9). Steers on GR-NS had the highest ($P < 0.05$) concentration of trans-11 vaccenic acid (3.08%), whereas GR-CS or LG without supplementation did not differ (2.16-2.42%). Our study reported similar percentages for trans-11 vaccenic acid as other studies (Corriher et al., 2009; Duckett et al., 2009). Steers on LG-NS had the highest ($P < 0.05$) concentration of linolenic acid (0.7 %). Corn supplementation on legume lowered ($P < 0.05$) linolenic acid concentration bud did not alter linolenic acid for grass pastures regardless of supplement. The increased linolenic acid concentration seen in the LG-NS treatment is likely a result of increased rumen bypass often seen in more rapidly digestibly forages. Our values for linolenic acid are similar to the work of Duckett et al. (2009), but lower than other studies that examined the effects of different energy supplements with forage on FA profile (Baublits et al., 2006; Schor et al., 2007)

Corn supplementation increased ($P < 0.05$) myristic (C14:0) and palmitic (C16:0) acid concentrations. Baublits et al. (2006) also reported an increase in palmitic acid content of the LM for supplemented steers, but found no difference in myristic acid. In a study comparing concentrate and pasture finishing, Duckett et al. (2013) reported increased LM concentrations of myristic and palmitic. In contrast to these studies, a review by Schor et al. (2007) reported no differences in palmitic acid concentration of the LM between five different supplementation rates, including a grain-based and silage-based feedlot ration.

There was a tendency for CS to increase oleic acid and total MUFA of the LM. Other studies have reported significant increases in MUFA as energy supplementation increases in the diet (Schor et al., 2007; Latimori et al., 2008). In contrast, Corriher et al. (2009) found no differences in total MUFA between pasture and pasture plus corn supplementation. Corn supplementation decreased ($P < 0.05$) pentadecanoic acid (C15:0), CLA *cis*-9 *trans*-11, arachidic acid (C:20), eicosapentaenoic acid (EPA, C20:5) and total omega 3 FA. Baublits et al. (2006) reported a decrease in pentadecanoic acid for supplemented cattle. Our findings for CLA *cis*-9 *trans*-11 are in agreement with other studies that reported a decrease in CLA as energy supplementation increases (Schor et al., 2007; Latimori et al., 2008; Corriher et al., 2009). Interestingly, Buablits et al. (2006) reported no differences in CLA *cis*-9 *trans*-11 between supplemented and pasture-only cattle. Though CLA *cis*-9 *trans*-11 concentrations, on a g/100g basis, were found lower in CS compared to NS, when CLA *cis*-9 *trans*-11 concentrations were adjusted by total lipid, no differences ($P > 0.05$) were detected.

There was a strong trend ($P < 0.057$) for CS to decrease docosapentaenoic acid (DPA, C22:5). In addition, CS also reduced ($P < 0.05$) concentrations of total odd-chain FA and omega-3 FA. A decrease in omega-3 FA as supplementation increases in the diet is well documented (Baublits., 2006; Schor et al., 2007; Latimori et al., 2008, Duckett et al., 2009) and expected as forage tissue is higher in omega-3 FA compared to grains which are rich in omega-6 FA. The decrease in omega-3 FA resulted in a higher (P < 0.05) omega-6 to omega-3 ratio (3.09 vs 2.39), though still within the recommended range by health professionals (Department of Health, 1994). Other studies have reported increased omega-6 to omega-3 ratios as supplementation increases in the diet (Baublits., 2006; Schor et al., 2007; Latimori et al., 2008). Similar to our work all of these studies reported values within the 4:1 ratio recommended by health professionals.

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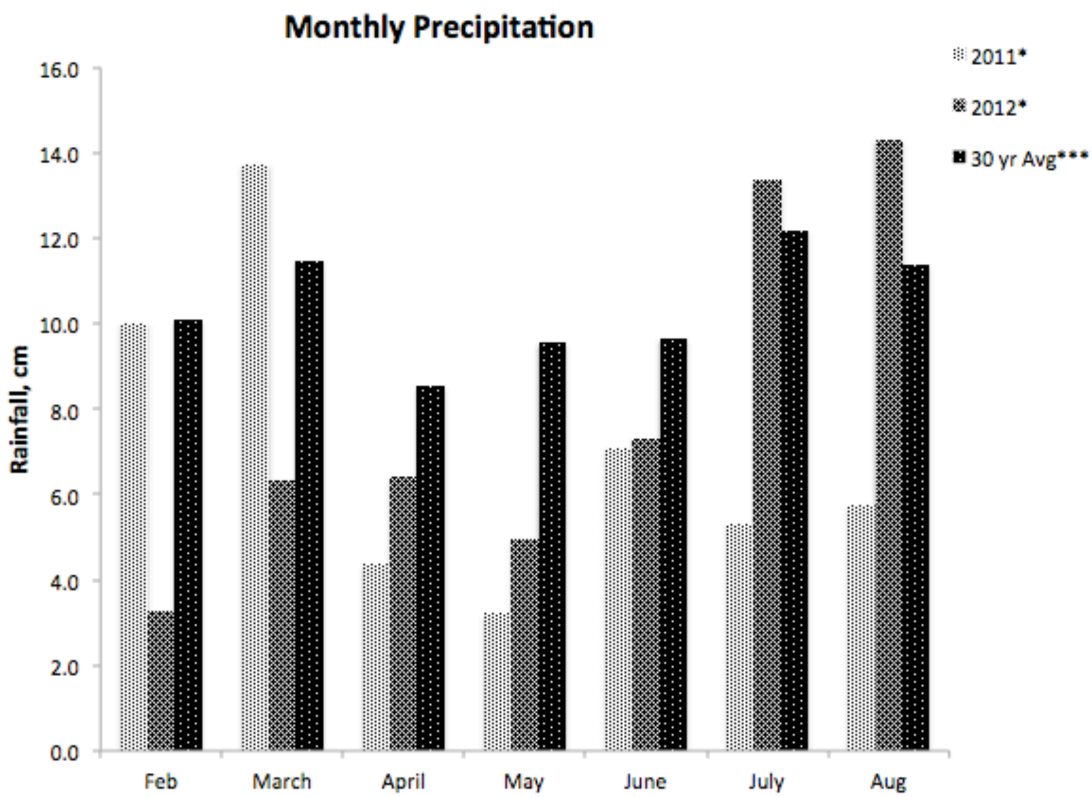

Figure 2.1. Monthly precipitation (cm) during the 2011 and 2012 grazing periods.

*2011 and 2012, Sandy Springs, South Carolina (wunderground.com/history)

***1980-2010, Grenville-Spartanburg Airport, South Carolina (erh.noaa.gov/gsp)

Table 2.1. Composition of Kowpoke One to One Mineral-Vitamin Supplement[1]

Item, minimum	Guaranteed analysis
Calcium, %	12.0
Phosphorus, %	12.0
Salt (NaCl), %	11.0
Magnesium, %	3.0
Potassium, %	1.0
Cobalt, ppm	50
Copper, ppm	240
Iodine, ppm	70
Manganese, ppm	750
Selenium, ppm	26
Zinc, ppm	950
Vitamin A, IU/kg	45,300
Vitamin D-3, IU/kg	4,530
Vitamin E, IU/kg	4.53

[1]Sweetlix, Mankato, Minnesota

Table 2.2. Composition of Sweetlix Bloat Guard® Pressed Block[1]

Item	Guaranteed analysis
Poloxalene, g kg^{-1}	65.95
Crude Protein, minimum %	4
Crude Fat, minimum %	0.05
Crude Fiber, maximum %	12.5
NaCl, minimum %	19.5
NaCl, maximum %	23
Potassium, minimum %	1.8
Iodine, minimum ppm	43
Selenium, minimum ppm	13

[1]Sweetlix, Mankato, Minnesota

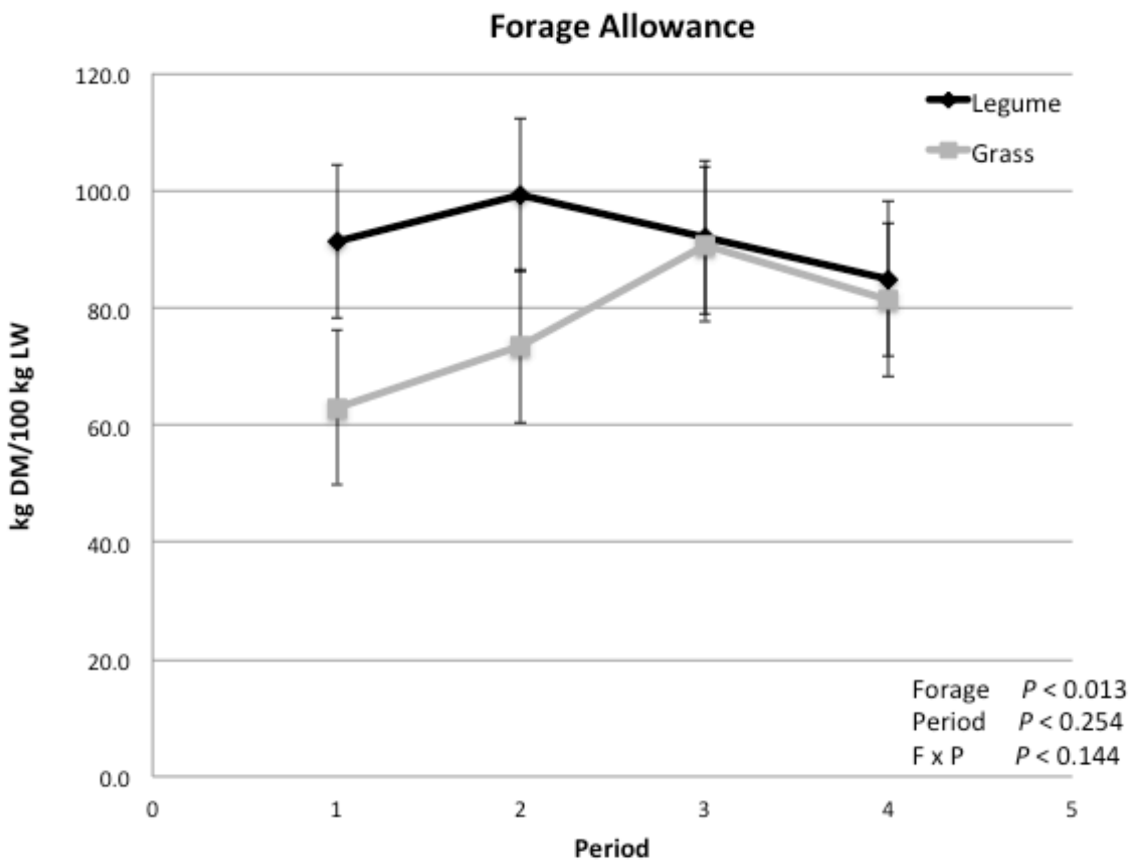

Figure 2.2. Forage allowance for legume and grass forage sequences

Table 2.3. *Mineral, proximate, and fatty acid concentration in herbage of legume and grass forage chains*

	Forage			Period					*P*-value		
	Grass	Legume	SEM	1	2	3	4	SEM	Forage	Period	F x P
Minerals											
P, %	0.30	0.31	0.01	0.29	0.34	0.28	0.30	0.02	0.605	0.032	0.188
K, %	2.26	1.96	0.12	2.26	2.31	2.02	1.86	0.10	0.069	0.174	0.593
Ca, %	0.45	1.03	0.02	0.83	0.74	0.71	0.67	0.03	<0.001	0.041	0.074
Mg, %	0.35	0.35	0.03	0.35	0.30	0.38	0.37	0.03	0.784	0.034	0.082
S, %	0.25	0.27	0.01	0.28	0.27	0.25	0.24	0.02	0.041	0.119	0.783
Zn, ppm	38.68	41.52	2.37	33.18	40.69	44.95	41.58	3.89	0.444	0.165	0.373
Cu, ppm	8.91	8.41	0.51	7.06	9.68	8.63	9.26	0.84	0.538	0.145	0.201
Mn, ppm	64.11	42.04	2.80	52.23	46.88	49.36	63.85	4.78	<0.001	0.168	0.107
Fe, ppm	222.63	138.87	33.19	208.15	182.78	149.72	182.36	38.74	0.002	0.414	0.127
Na, ppm	73.31	114.28	37.56	138.57	109.18	70.70	56.71	37.78	0.139	0.003	0.938
Proximate											
NDF	51.23	29.52	3.19	41.05	38.02	39.81	41.62	3.24	<0.001	0.368	0.248
ADF	26.83	24.33	1.11	26.83	25.33	24.56	26.41	1.11	0.528	0.577	0.281
CP	18.96	24.07	1.85	21.03	20.52	22.26	22.26	2.11	0.002	0.689	0.821
Lipid	2.28	1.89	0.64	1.94	2.03	2.21	2.15	0.65	0.066	0.727	0.146
Ash	6.99	6.99	0.35	7.64	7.19	6.81	6.32	0.31	0.996	0.005	0.447
Fatty Acids											
C16:0	16.99	22.75	1.02	21.24	19.39	18.69	20.17	1.08	0.002	0.527	0.225
C18:1c9	2.06	3.31	0.62	3.34	2.20	2.17	3.03	0.64	<0.001	0.018	0.321
C18:2	14.47	22.45	0.64	21.00	20.93	15.13	16.82	1.59	<0.001	0.055	0.082
C18:3	64.34	49.95	2.98	51.07	58.54	62.88	56.08	3.20	<0.001	0.008	0.206
mg/g	23.57	17.38	3.82	17.13	21.18	21.66	21.94	3.54	0.192	0.119	0.740

Table 2.4. Composition of cracked corn

	% DM					ppm			
Mineral	P	K	Ca	Mg	S	Zn	Cu	Mn	Fe
	0.32	0.40	0.01	0.12	0.10	23.50	4.19	6.44	69.38

Proximate	NDF	ADF	CP	Lipid	Ash
	12.90	2.99	7.60	4.20	1.55

Fatty Acid	C16	C18	C18:1cis9	C18:2	C18:3
	12.82	1.85	26.22	57.68	1.43

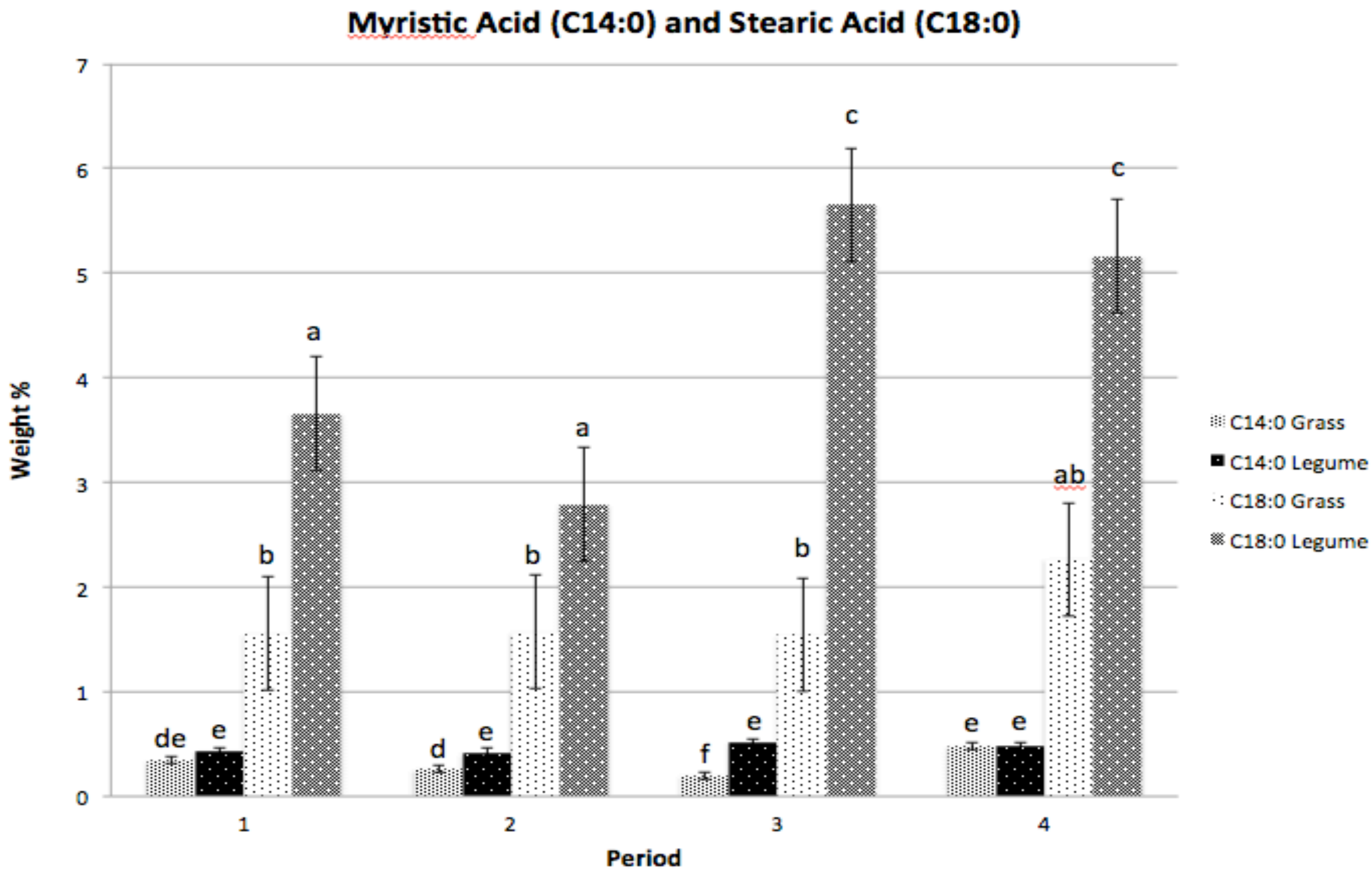

Figure 2.3. Treatment interaction for myristic (C14:0) and stearic acid (C18:0)

[abc]Means for Stearic Acid (C18:0) with different superscripts differ ($P < 0.05$)

[def]Means for Myristic Acid (C14:0) with different superscripts differ ($P < 0.05$)

Table 2.5. The effect of forage type and supplementation on animal performance and carcass quality

Item	Forage Type (FT)		Supplementation (S)			*P*-value		
	Grass	Legume	No Corn	Corn	SEM	FT	S	FT x S
No. of observations	*16*	*16*	*16*	*16*				
Final Weight, kg	518	529	517	530	35.4	0.180	0.100	0.747
ADG, kg/day	0.72	0.81	0.64	0.89	0.12	0.065	<0.001	0.934
HCW, kg	303	317	302	318	23.5	0.010	0.004	0.564
Dressing percentage	58.5	59.9	58.5	59.9	0.35	0.011	0.008	0.594
Fat thickness, cm	0.85	0.95	0.82	0.98	0.03	0.232	0.059	0.121
KPH[1], %	1.4	1.7	1.4	1.7	0.16	0.180	0.088	0.560
USDA yield grade	2.5	2.7	2.5	2.8	0.10	0.148	0.045	0.065
USDA quality grade[2]	4.5	4.7	4.3	4.9	0.33	0.609	0.068	0.396

[1]Kidney, pelvic, heart fat (KPH). [2]USDA quality grade scale 3 = Low Select, 4 = High Select, 5 = Low Choice

Table 2.6. The effect of forage type and supplementation on longissiimus muscle color and subcutaneous fat color

	Forage Type (FT)		Supplementation (S)			*P*-value		
Item	Grass	Legume	No Corn	Corn	SEM	FT	S	FT x S
No. of observations	*16*	*16*	*16*	*16*				
Longissimus muscle color								
L*	41.0	41.4	41.0	41.4	0.45	0.355	0.272	0.491
a*	26.2	26.5	26.5	26.2	1.94	0.378	0.499	0.294
b*	10.6	10.8	10.7	10.8	0.95	0.266	0.563	0.105
Longissimus muscle pH								
pH	5.43	5.43	5.43	5.42	0.04	1.00	0.571	0.097
Subcutaenous fat color								
L*	75.7	76.4	76.4	75.8	0.69	0.473	0.548	0.915
a*	6.5	6.9	7.1	6.3	2.81	0.434	0.110	0.809
b*	19.3	19.5	18.3	20.5	1.84	0.818	0.005	0.182

Table 2.7. The effect of forage type and supplementation on proximate, cholesterol, α-tocopherol, and minerals of the LM

	Forage Type (FT)		Supplementation (S)			*P*-value		
Item	Grass	Legume	No Corn	Corn	SEM	FT	S	FT x S
No. of observations	*16*	*16*	*16*	*16*				
Proximate, g/100 g								
Moisture	72.73	73.14	73.34	72.53	0.01	0.332	0.058	0.393
Protein	21.29	20.98	21.06	21.21	0.63	0.104	0.412	0.248
Lipid	4.08	3.69	3.70	4.07	0.26	0.464	0.485	0.314
Ash	1.10	1.09	1.08	1.11	0.10	0.866	0.302	0.994
Cholesterol, mg/100g	52.61	52.96	53.73					
α-Tocopherol, µg/100 g	396.16	249.8	293.09	352.86	30.6	<0.001	0.109	0.283
Mineral, mg/100g								
Calcium	7.17	9.02	8.90	7.29	2.81	0.027	0.053	0.529
Magnesium	21.43	21.14	21.23	21.34	0.24	0.251	0.676	0.195
Sodium	36.66	34.92	35.13	36.46	0.76	0.093	0.196	0.458
Potassium	356.7	348.4	351.2	359.2	7.98	0.054	0.524	0.599
Zinc	3.51	3.48	3.44	3.55	0.18	0.849	0.519	0.378
Iron	1.88	1.93	1.91	1.90	0.05	0.381	0.794	0.693

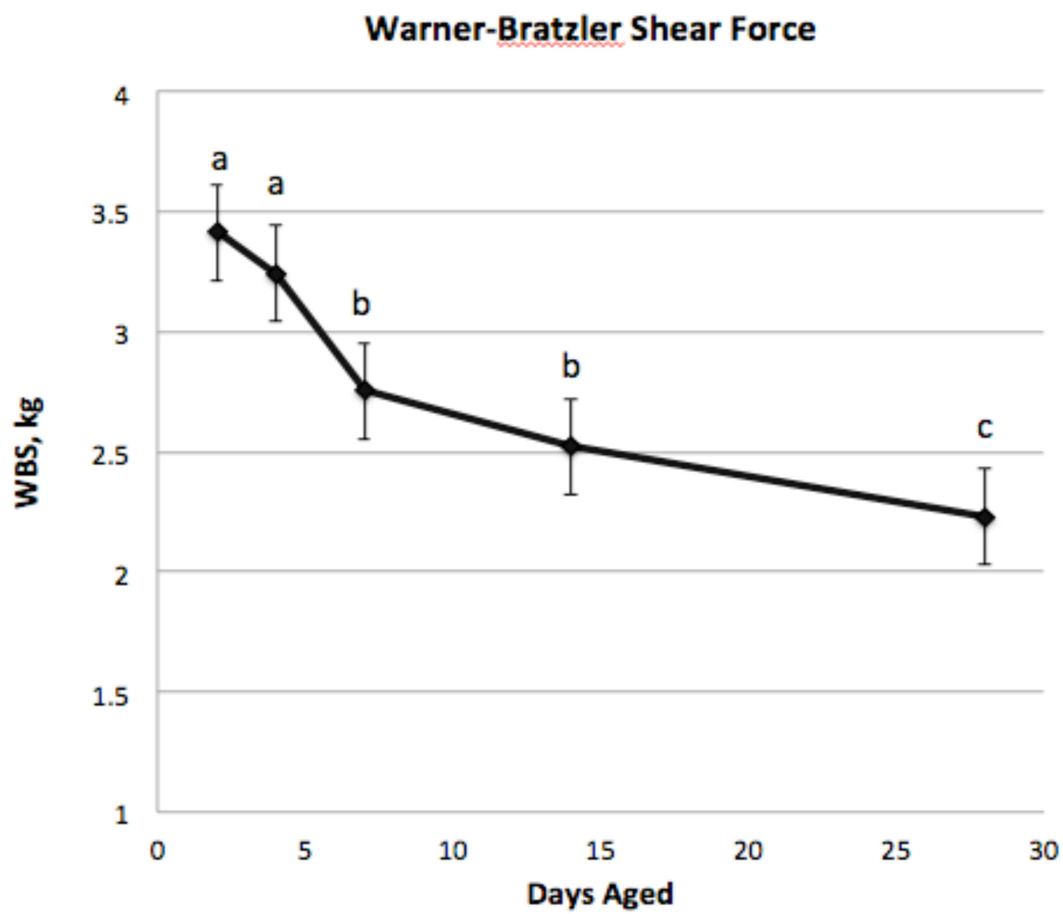

Figure 2.4. Effect of postmortem aging on tenderness of the LM
[abc]Means with different superscripts differ ($P < 0.05$)

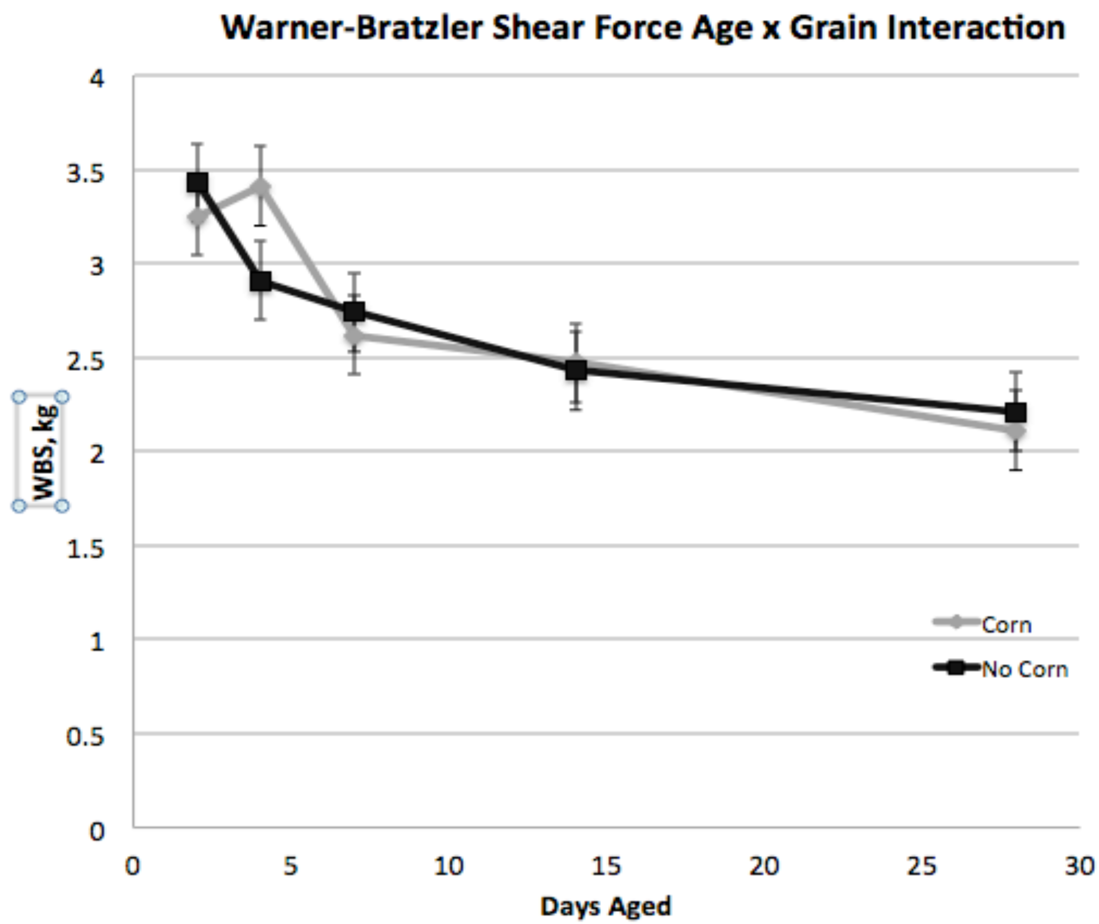

Figure 2.5. Age by grain treatment interaction for Warner-Bratzler shear force

Table 2.8. The effect of forage type and supplementation on fatty acid profile in the LM

	Forage Type (FT)		Supplementation (S)			*P*-value		
Item	Grass	Legume	No Corn	Corn	SEM	FT	S	FT x S
No. of observations	*16*	*16*	*16*	*16*				
Fatty acid, weight %								
C14	2.63	2.68	2.48	2.83	0.07	0.722	0.018	0.310
C14:1	1.58	1.56	1.57	1.56	0.06	0.692	0.790	0.814
C15	0.94	0.92	0.96	0.90	0.27	0.149	0.006	0.203
C16	27.24	27.33	26.78	27.79	0.19	0.804	0.011	0.502
C16:1 cis-9	3.09	3.27	3.08	3.28	0.21	0.375	0.335	0.421
C17	0.95	0.98	0.99	0.93	0.02	0.475	0.120	0.722
C18	15.62	14.39	15.35	14.66	0.34	0.029	0.201	0.788
C18:1 trans-9	0.24	0.14	0.19	0.19	0.19	0.028	0.915	0.652
C18:1 cis-9	36.84	37.32	36.58	37.58	1.54	0.384	0.079	0.135
C18:1 cis-11	0.98	1.14	1.11	1.01	0.06	0.076	0.265	0.287
C18:2 cis 9, 12	2.61	2.87	2.83	2.65	0.33	0.138	0.274	0.456
C18:2 CLA cis-9, trans-11	0.58	0.53	0.60	0.51	0.12	0.197	0.020	0.700
C18:2 CLA trans-10, cis-12	0.25	0.24	0.24	0.24	0.01	0.121	0.614	0.178
C18:2 CLA trans, trans	0.48	0.47	0.48	0.47	0.02	0.480	0.686	0.154
C18:2 CLA cis- 9, cis-11	0.48	0.48	0.48	0.48	0.02	0.065	0.303	0.199
C20	0.06	0.05	0.06	0.05	0.05	0.063	0.047	0.454
C20:4 cis-5, 8, 11, 14	0.99	1.04	1.08	0.95	0.11	0.634	0.240	0.929
C20:5 cis-5, 8, 11, 14, 17	0.14	0.14	0.16	0.12	0.01	0.730	0.003	0.992
C22:5 cis-4, 7, 10, 13, 16, 19	0.35	0.37	0.39	0.32	0.03	0.532	0.057	0.319
C22:6 cis-4, 7, 10, 13, 16, 19	0.05	0.06	0.07	0.04	0.04	0.609	0.152	0.837

Total unidentified	3.19	3.45	3.53	3.13	1.65	0.444	0.136	0.139
SFA	45.49	44.41	44.61	45.81	0.32	0.019	0.142	0.956
MUFA	40.47	41.11	40.20	41.38	1.68	0.318	0.071	0.270
Odd-chain	1.48	1.48	1.54	1.42	0.04	0.968	0.021	0.429
n-6 PUFA	2.72	2.99	2.94	2.76	0.33	0.130	0.312	0.548
n-3 PUFA	1.02	1.15	1.24	0.93	0.08	0.072	<0.001	0.237
n-6:n-3 ratio	2.77	2.72	2.39	3.09	0.51	0.548	<0.001	0.195

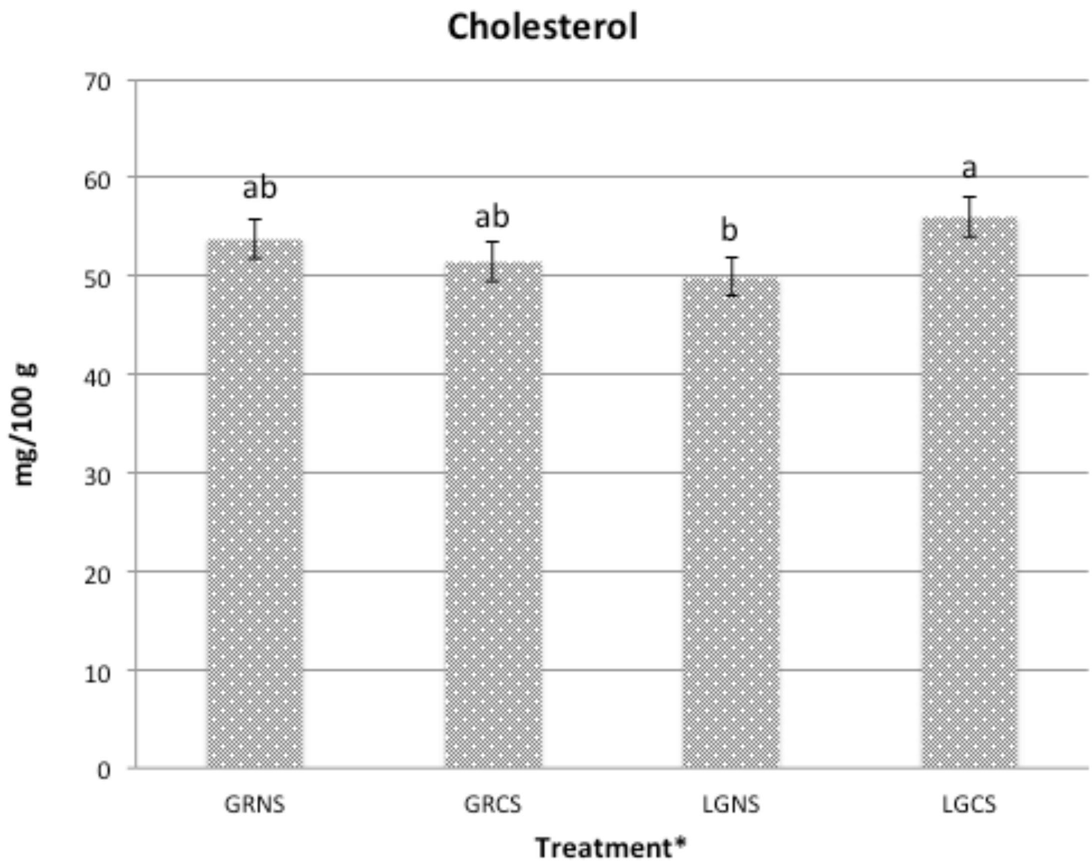

Figure 2.6. Treatment interaction for cholesterol

*Treatment: grass with no corn (GRNS), grass with corn (GRCS), legume with no corn (LGNS), legume + corn (LGCS)

[ab]Means with different superscripts differ ($P < 0.05$)

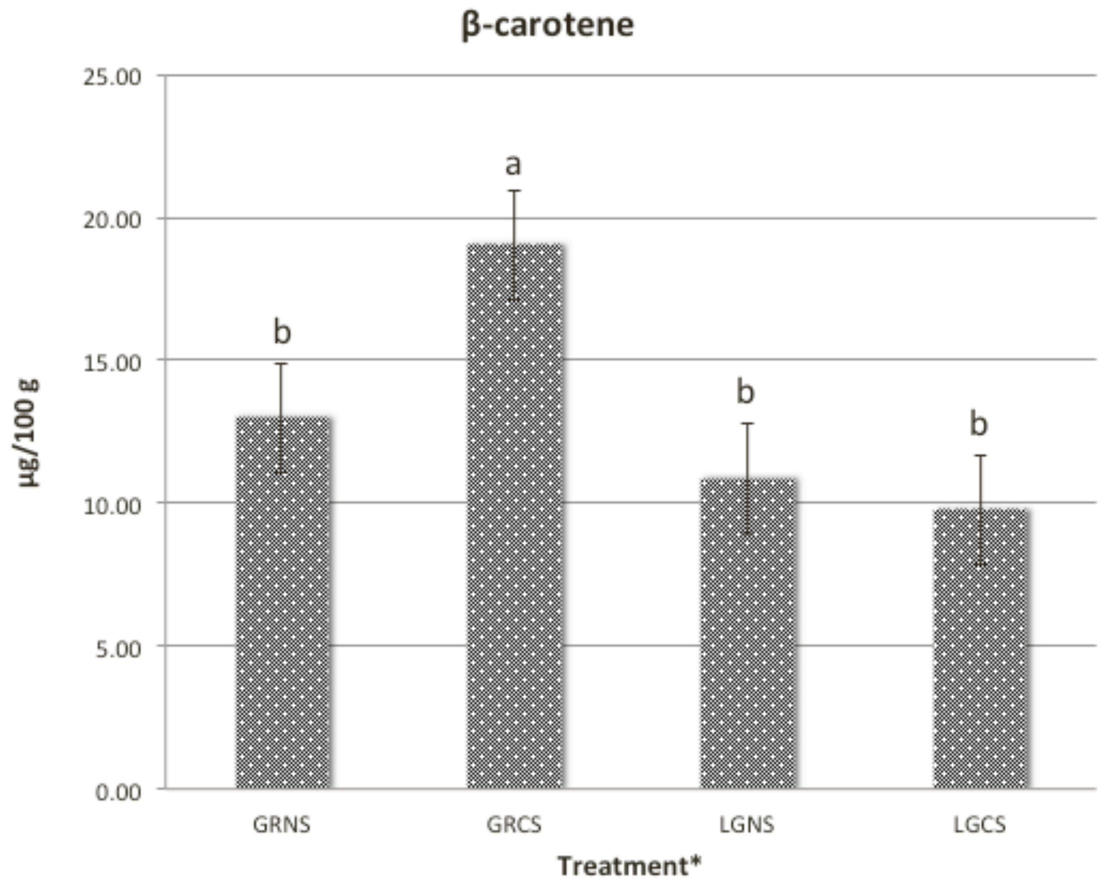

Figure 2.7. Treatment interaction for β-carotene

*Treatment: grass with no corn (GRNS), grass with corn (GRCS), legume with no corn (LGNS), legume + corn (LGCS)

[ab]Means with different superscripts differ ($P < 0.05$)

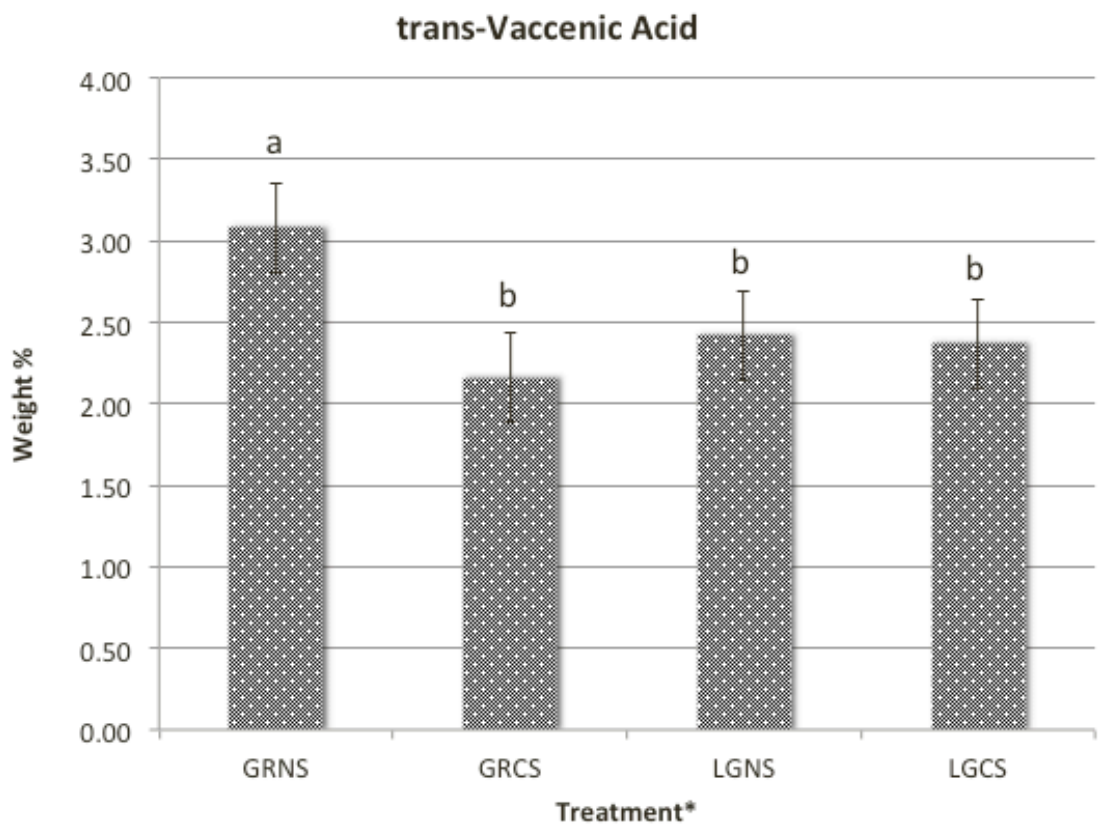

Figure 2.8. Treatment interaction for trans-vaccenic acid (C18:1 *t*-11)

*Treatment: grass with no corn (GRNS), grass with corn (GRCS), legume with no corn (LGNS), legume + corn (LGCS)

^{ab}Means with different superscripts differ (P < 0.05)

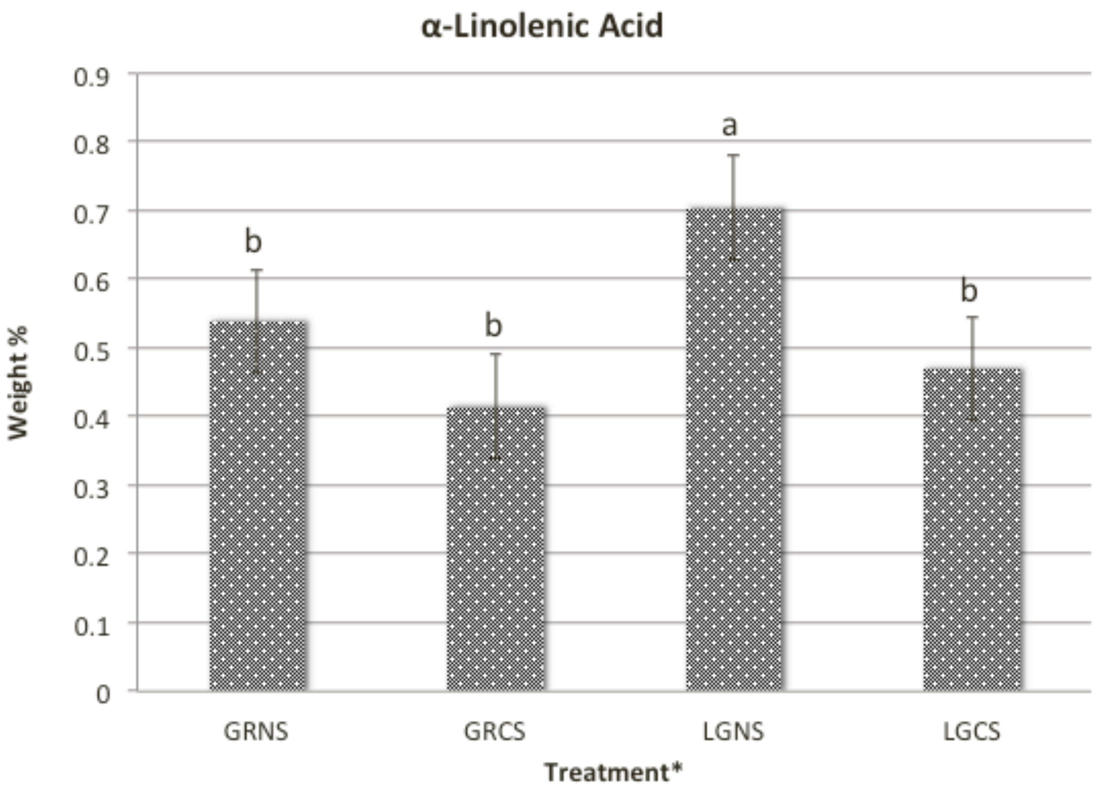

Figure 2.9. Treatment interaction for α-linolenic acid (C18:3)

*Treatment: grass with no corn (GRNS), grass with corn (GRCS), legume with no corn (LGNS), legume + corn (LGCS)

[ab]Means with different superscripts differ ($P < 0.05$)